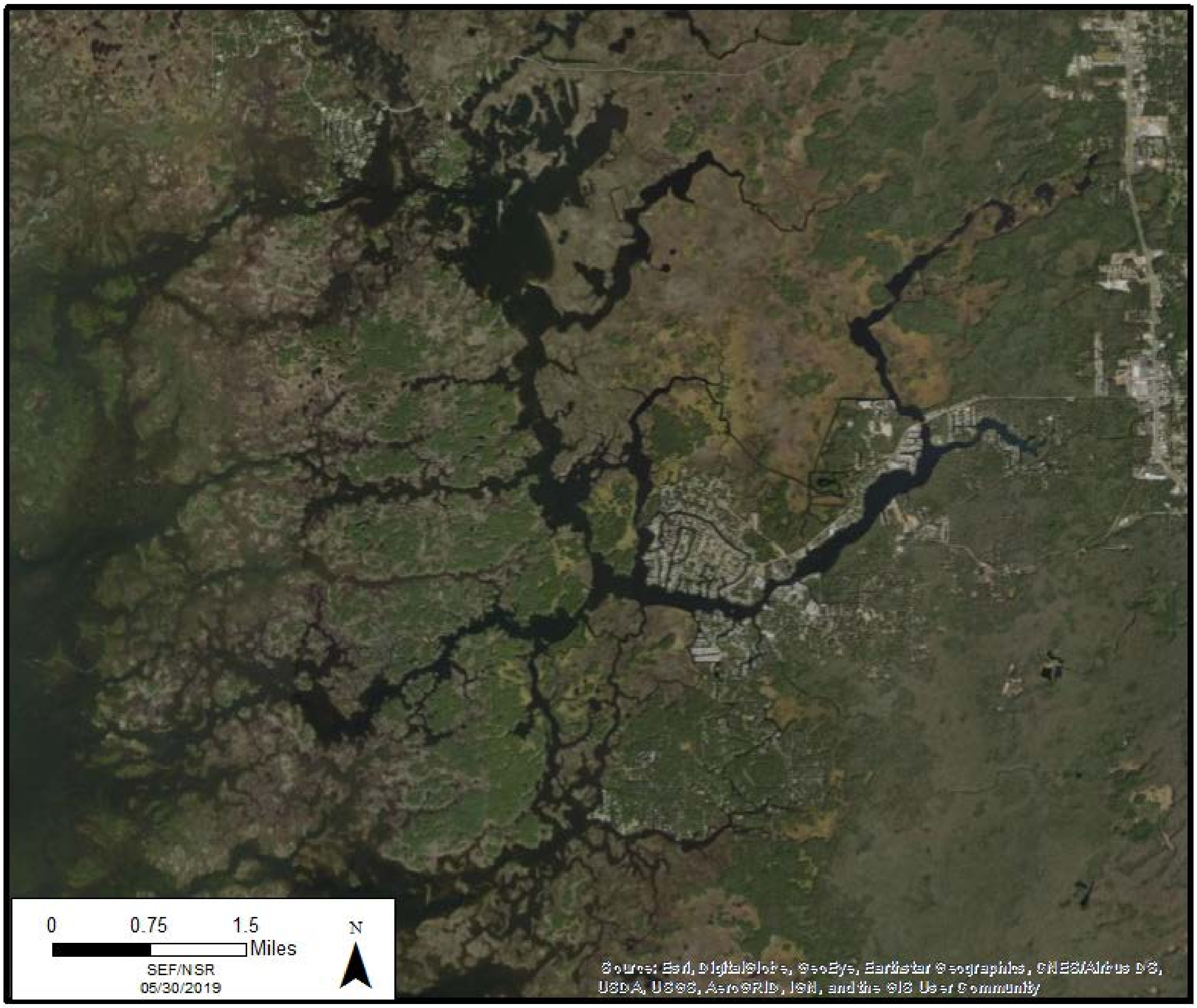
Reevaluation of Minimum Flows for the Homosassa River System

Final Draft



October 2019

Southwest Florida Water Management District

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Brooksville, Florida 34604-6899

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The geological evaluation and interpretation contained in the report entitled *Reevaluation of Minimum Flows for the Homosassa River System* has been prepared by or approved by a Certified Professional Geologist in the State of Florida, in accordance with Chapter 492, Florida Statutes.

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EXECUTIVE SUMMARY

The Southwest Florida Water Management District (District) is directed by the Florida Legislature to establish minimum flows for rivers and springs within its jurisdiction. Minimum flows are defined in Section 373.042(1) Florida Statutes as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.” Once adopted into District rules, minimum flows can be used for water supply planning, water use permitting and environmental resource regulation.

This report identifies recommended minimum flows that were developed as part of the reevaluation of minimum flows currently established for the Homosassa River System. District Rule (Section 40D-8.041(16), Florida Administrative Code) establishes minimum flows for the Homosassa River System, and requires reevaluation of the minimum flows in 2019, six years from initial adoption in 2013. As part of the reevaluation, recommended minimum flows were developed using the best information available, as required by the Florida Statutes, and were based on all relevant environmental values identified in the Florida Water Resource Implementation Rule (Section 62-40.473, Florida Administrative Code) for consideration when setting minimum flows.

The Homosassa River System includes several named rivers and creeks, surface drainage basins, a spring group consisting of many individual spring vents, and an associated springshed. Rule 40D-8.041(16) adopted in 2013 states the Homosassa River System includes the watercourse from the Homosassa Main Springs Complex to the Gulf of Mexico, including the southeast fork of the Homosassa River, Halls River, Hidden River and all named and unnamed springs that discharge to these rivers. This description is applicable for the current minimum flows reevaluation for the system, which can alternatively be referred to as the Homosassa River / Homosassa Spring Group. The Homosassa River flows approximately 8 miles to its mouth near Shell Island in the Homosassa Bay region of the Gulf of Mexico. The Homosassa River system is fed by 24 named springs. The entire system is influenced by tides and salt water from the Gulf of Mexico. All non-artificial water bodies in the Homosassa River system are classified as Outstanding Florida Waters, a designation associated with Florida’s anti-degradation policy (Rule 62-302.700, F.A.C.) In addition, the Homosassa River is designated a Southwest Florida Water Management District Surface Water Improvement and Management (SWIM) Priority Waterbody and as such, has a comprehensive SWIM Plan approved by the Springs Coast Steering Committee and the District’s Governing Board in August 2017.

The recommended minimum flows for the Homosassa River system are 95 percent of flows that would occur in the absence of withdrawal impacts; allowing up to a 5 percent reduction from unimpacted flows. This recommendation is made on the basis of temperature-based habitat for Common Snook. Groundwater modeling (Northern District Model version 5.0) indicates current (2015) withdrawal impacts reduce flows by 1.9 percent, with projected demand increasing this to as much as 3.0 percent by 2035. Because current withdrawal impacts are less than the maximum allowable 5 percent reduction, development of a recovery strategy concurrent with adoption of the proposed minimum flow would not be necessary at this time. Likewise, a prevention strategy would not be needed because projected withdrawal impacts of 3.0 percent are lower than the maximum allowable of 5 percent reduction associated with the proposed minimum flow.

Updates to data collection and analysis supported the minimum flow reevaluation included use of Northern District Model version 5 for groundwater modeling, new shoreline vegetation mapping, submerged aquatic vegetation surveys, oyster health assessment, a barnacle survey, fish community sampling, development of a new hydrodynamic model for characterizing system salinities, temperatures, and water levels, use of a new criterion associated with temperature-based habitat for Common Snook, and new water quality analysis. Findings associated with use of these improved data and tools are generally consistent with the previous work completed for the District's original minimum flows evaluation, which identified a minimum flow that would allow up to a 3 percent reduction in unimpacted flows.

A peer review for this minimum flows reevaluation was conducted in two phases from February through June 2019. The first phase was an initial peer review that culminated in recommendations for changes to the report documentation and analyses and provided initial conclusions on the technical defensibility of the minimum flows reevaluation. Following submittal of the Initial Peer Review Report, District staff made changes to the minimum flows report and one of the appendices along with providing additional technical documents in response to the recommendations. Based on the District responses to comments, additional technical documentation, and the updated documents, no unresolved recommendations remain, and the panel supported the conclusions presented within the minimum flows report and the use of the thermal habitat for Common Snook as the primary metric.

Simulations of reduced flows were based on gaged flows at the United States Geological Survey (USGS) gaging stations Homosassa Springs at Homosassa Springs, FL (No. 02310678) and SE Fork Homosassa Spring at Homosassa Springs, FL (No. 02310688). The long-term average combined flow for all "approved" daily data from October 1, 2000 to October 12, 2017 at these gages was 146 cubic feet per second (cfs). Adjusted for withdrawal impacts of 1.9 percent, the long-term unimpacted flows would average 149 cfs, and minimum flows, corresponding to 95 percent of the unimpacted flow, would average 141 cfs over the same time period.

The District will continue to implement its general, three-pronged prevention strategy that includes monitoring, protective water-use permitting, and regional water supply planning to ensure that the adopted minimum flow for the system continues to be met. In addition, the District will continue to monitor flows in the system to further our understanding of the structure and functions of the Homosassa River System and to develop and refine our minimum flow development methods.

CHAPTER 1 - INTRODUCTION

1.1 2013 Minimum Flows Evaluation and Rule

This report documents a reevaluation of the minimum flow established for the Homosassa River System in 2013 by the Southwest Florida Water Management District (SWFWMD or District). The Homosassa River System includes the watercourse from the Homosassa Main Springs Complex to the Gulf of Mexico, including the southeast fork of the Homosassa River, Halls River, Hidden River and all named and unnamed springs that discharge to these rivers. This system description is applicable for the current minimum flows reevaluation; however, the system may also alternatively be referred to as the Homosassa River / Homosassa Spring Group.

The currently established minimum flow for the system is supported by the technical data, analyses, methodologies, models and assumptions described in a 2012 District report (Leeper et al. 2012). The 2012 report was preceded by a 2010 version that was presented to the District Governing Board in July 2010, subjected to scientific peer-review (Hackney et al. 2010), and reviewed by numerous additional stakeholders. The review process led to the completion of additional analyses by District staff and ultimately to updating of the minimum flow recommendation from the 2010 report for inclusion within the 2012 report.

The minimum flow recommendation included in the 2012 report supported an allowable 3 percent reduction from unimpacted flows, that is, an allowable 3 percent reduction from flows expected in the absence of water-withdrawal impacts. The recommendation, which is equivalent to maintaining 97% of unimpacted flows, was based on protection of salinity habitats associated with bottom areas exposed to average salinities less than or equal to 3 psu.

The District Governing Board accepted the 2012 report in October 2012. They also approved initiation of rulemaking at that time, which led to the 2013 adoption of Rule 40D – 8.041(17), Florida Administrative Code (F.A.C.) (Box 1), establishing the minimum flow for the Homosassa River System at 97% of the natural flow. The term “natural flow” identified in the rule is synonymous with “unimpacted flows”, as used in this minimum flow reevaluation report. The rule was adopted in 2013, therefore, according to 40D-8.041(17)(c), F.A.C., reevaluation of the minimum flow is scheduled to occur before the end of 2019.

Chapter 40D-8 (Florida Administrative Code)
Water Levels and Rates of Flow
40D-8.041 Minimum Flows.

(17) Minimum Flow for the Homosassa River System.

(a) For purposes of this rule, the Homosassa River System includes the watercourse from the Homosassa Main Springs Complex to the Gulf of Mexico, including the southeast fork of the Homosassa River, Halls River, Hidden River and all named and unnamed springs that discharge to these rivers.

(b) The Minimum Flow for the Homosassa River System is 97% of the combined natural flow as measured at the United States Geological Survey (USGS) Homosassa Springs at Homosassa Springs, FL Gage (No. 02310678), and the USGS SE Fork Homosassa Spring at Homosassa Springs, FL Gage (No. 02310688). Natural flow is defined for the purpose of this rule as the flow that would exist in the absence of water withdrawal impacts. The Minimum Flow at any point downstream from these Gages are measured as the previous day's natural flow at that point minus 3%.

(c) The District will reevaluate the Minimum Flow within six years of adoption of this rule.

Box 1. Rule 40D – 8.041(17) Florida Administrative Code.

1.2 Legal Directives and Use of Minimum Flows and Levels

1.2.1 Relevant Statues and Rules

The purpose of this report is to reevaluate the minimum flow for the Homosassa River System by establishing the minimum spring discharge necessary to prevent significant harm to the water resources and ecology of the area. The Florida Statutes (F.S.) and Florida Administrative Code (F.A.C.) provide the following guidance for setting minimum flows:

1. Section 373.042 of The Florida Water Resources Act of 1972 (Chapter 373, F.S.) directs the Department of Environmental Protection (DEP) or the District to establish minimum flows for all surface watercourses in the area. This section states that "the minimum flow and minimum water level shall be calculated by the department and the governing board using the best information available." This statute also establishes the priority list and schedule which is annually updated and approved by the Governing Board. Section 373.042, F.S., also allows for the establishment of an independent scientific peer review panel.
2. Section 373.0421, F.S., allows for considerations of changes and structural alterations. In cases where dams, or extensive channelization have altered the hydrology of a system for flood control and water supply purposes, the District attempts to balance protecting environmental values with the human needs that are met by these alterations. This section also determines that recovery and prevention strategies must be put in place if the system is not or is projected to not meet applicable minimum flows within the next 20 years.

3. Rule 62-40.473 of The Florida Water Resource Implementation Rule (Chapter 62-40, F.A.C.), provides goals, objectives and guidance regarding the establishment of minimum flows and levels. This rule defines the ten environmental values described in section 1.2.2 below that are to be considered when establishing minimum flows. In recognition of the fact that flows naturally vary, this rule also states that minimum flows should be expressed as multiple flows defining a hydrological regime to the extent practical and necessary.
4. Section 40D-8.041(17) within the District's Water Levels and Rates of Flow Rules (Chapter 40D-8, F.A.C.) describes the Minimum Flow for the Homosassa River System and establishes a schedule for its reevaluation (see section 1.1 above).

The District's Minimum Flows and Levels Program addresses all relevant requirements expressed in the Water Resource Implementation Rule and the Water Resources Act of 1972. The Homosassa River system is a flowing surface water course, and as such its volume of flowing water must be protected from significant harm. Establishing minimum flows that address all relevant legal requirements will support water-use permitting, water-supply planning and other water management activities that can provide this protection.

The District has developed specific methodologies for establishing minimum flows or minimum water levels for lakes, wetlands, rivers, springs and aquifers, subjected the methodologies to independent, scientific peer-review, and in some cases, adopted the methods into its Water Level and Rates of Flow Rule. In addition, regulatory components of recovery strategies necessary for the restoration of minimum flows and levels that are not currently being met have been adopted into the District's Recovery and Prevention Strategies for Minimum Flows and Levels Rule (Chapter 40D-80, F.A.C.). A summary of efforts completed for the District's Minimum Flows and Levels Program is provided by Hancock *et al.* (2010).

The District has established and codified minimum flows for 18 river segments into rule. Minimum flows recommendations, peer reviews, appendices with technical documents, and other related material are available from the District's Minimum Flows and Levels (Environmental Flows) Program web page.

1.2.2 Environmental Values

As part of its intention to provide goals, objectives, and guidance, Rule 62.40.473, F.A.C., within the Water Resource Implementation Rule, states that "consideration shall be given to natural seasonal fluctuations in water flows or levels, nonconsumptive uses, and environmental values associated with coastal, estuarine, riverine, spring, aquatic and wetlands ecology, including:

(a) Recreation in and on the water;
(b) Fish and wildlife habitats and the passage of fish;
(c) Estuarine resources;
(d) Transfer of detrital material;
(e) Maintenance of freshwater storage and supply;
(f) Aesthetic and scenic attributes;
(g) Filtration and absorption of nutrients and other pollutants;
(h) Sediment loads;
(i) Water quality; and
(j) Navigation.

1.3 Vertical Datum

The District is in the process of converting from use of the National Geodetic Vertical Datum of 1929 (NGVD 29) to use of the North American Vertical Datum of 1988 (NAVD 88) for measuring and reporting vertical elevations. While the NGVD 29 datum is used for most elevation values included within this report, in some circumstances elevation data were collected or reported relative to mean sea level or relative to NAVD 88. As necessary, elevations relative to the differing datums were converted to alternate datums in accordance with the District's internal operating procedure for minimum flows and levels data collection, summarization, reporting and rule development (Leeper 2016).

1.4 Development of Minimum Flows and Levels in the Southwest Florida Water Management District

The development of minimum flows proceeds from the following premises:

1. Alterations to hydrology will have consequences for the environmental values listed in Rule 62.40.473, F.A.C., and section 1.2.2 of this report.

2. We can measure criteria linked to these environmental values. We can also quantify links between flow alterations and measured criteria.

3. Flows may be reduced from non-withdrawal impacted conditions yet be of sufficient magnitude to protect the water resources and ecology associated with identified environmental values.

An established body of scientific work supports all three of these premises by relating hydrology, ecology, and human-use values associated with water resources (Poff and Zimmerman 2010, Postel and Richter 2012). For example, consider a pristine, unaltered river with no local groundwater or surface water withdrawal impacts. We expect this hydrologic regime to respond in proportion to the magnitude of any new water withdrawals. Small withdrawals may produce a new hydrologic regime that is indistinguishable from the historical, natural regime, while large withdrawals could produce substantially altered regimes. An intermediate hydrologic regime will protect the water resources and ecology from significant harm while allowing for deviation from the historical hydrological habitat. Our objective is to define such an intermediate hydrologic regime that prevents significant harm yet allows for withdrawals that may shift the regime away from historical or theoretically optimal conditions.

Rivers demonstrate a range of flows in response to both short- and long-term rainfall patterns. The typical pattern of variation in flows is termed a "hydrologic regime". The environmental flows literature supports protecting the natural hydrologic regime (Hill *et al.* 1991, Richter *et al.* 1996, Poff *et al.* 1997, Postel and Richter 2012, Annear *et al.* 2004, Olsen and Richter 2006). The District's approach to developing minimum flows, and those used by other Florida water management districts (South Florida Water Management District 2002, Water Resource Associates, Inc. *et al.* 2005, Mace 2007, Neubauer *et al.* 2008) have been developed to help maintain natural hydrologic regimes, albeit with some allowance for water withdrawals.

Based on the importance of the hydrologic regime to river system integrity, the District has employed a percent-of-flow approach for establishing minimum flows (Flannery et al. 2002). Percent-of-flow approaches have been advocated for minimum flow determinations world-wide (Richter et al. 2011). The District's percent-of-flow method identifies flow reductions as percentages of flows that may be withdrawn directly from a river or from aquifers that contribute flows to a river without causing significant harm. By proportionally scaling water withdrawals to the rate of flow, the percent-of-flow approach is considerably more protective of flow variability than simple low-flow thresholds (Richter et al. 2011).

For minimum flow evaluations of some surface-water runoff driven rivers in the District, the percent-of-flow approach has been superimposed on seasons referred to as "blocks." In these runoff-dominated systems, three blocks are typically identified, with each associated with specific, allowable percent-of-flow reductions. However, while flow in the Homosassa River demonstrates some seasonal variation, it does not exhibit strong, distinct seasonal patterns which would necessitate two or more percentages to be applied at different times of year. Therefore, it is appropriate to establish a single allowable percent-of-flow reduction which applies to the entire year for the Homosassa River System.

The development of minimum flows for coastal systems such as the Homosassa River System necessarily involves the evaluation of flow effects on downstream estuaries. Estuaries account for approximately three-quarters of the Florida coastline (Kleppel *et al.* 1996) and these habitats serve as spawning areas, nurseries or other habitat for more than 95 percent of Florida's recreationally and commercially harvested fish, shellfish and crustaceans (Florida Fish and Wildlife Conservation Commission 2007). Thus, we must also take into consideration how changing flows in rivers can subsequently impact these coastal communities.

1.4.1 Significant Harm

Minimum flows must be established to prevent significant harm to the water resources or ecology of the Homosassa River System (Section 373.042, F.S.). However, no definition of significant harm is given in the statute. This makes the District or DEP responsible for determining the conditions that constitute significant harm in each system.

The District uses two categories of criteria for determining significant harm:

1) natural breakpoints, inflections, or thresholds; and
2) presumptive, habitat- or resource-based criteria.

When available, natural breakpoints, inflections, or thresholds are used. For example, in perennially flowing freshwater systems, the fish passage criterion associated with a threshold water depth of 0.6 ft is used to establish a minimum low flow threshold for promoting fish passage and flow continuity. Another threshold-based criterion used for freshwater lotic systems is the lowest wetted perimeter inflection point, where inflections in curves relating depth and wetted perimeter are used to determine threshold flows for significant harm.

In the Homosassa River system, the District is responsible for collecting and analyzing data on flows, water levels, salinity, temperature, water quality, shoreline vegetation, submerged aquatic vegetation, fish communities, invertebrates including oysters and barnacles, and manatees. Despite this abundance of data and review of environmental flows literature, no natural breakpoints, inflections, or thresholds associated with reduced flows have been identified for this system. In such instances when natural breakpoints, inflections, or thresholds are not available, the District has used a presumptive, 15% reduction in habitats or resources as a measure of significant harm. This 15% reduction criterion lacks the clear, ecological basis a natural threshold would carry, but does have advantages over a presumptive, flow-based criterion. For example, a 10% reduction in flows, applied across systems, may be overly restrictive in some systems and under-protective in others. By modeling changes to habitats and resources with incremental flow reductions, the 15% standard is sensitive to habitat or resource losses unique to each system. Because of this sensitivity, the 15% standard, as a habitat- or resource-based presumption is preferable to a flow-based presumption. It is also important to note that the consideration of multiple criteria based on the 15% change standard (e.g., assessing flow-related changes in various salinity and thermally-based habitats) is a means for dealing with uncertainty associated with individual criteria that may be inherent modeling approaches used for criteria assessment.

We typically express minimum flows as a fraction of unimpacted flows. Suppose a 10 percent reduction from unimpacted flows resulted in a 15 percent loss of fish habitat. In such a case, our minimum flow would be set at 90 percent of unimpacted flows to prevent loss of more than 15 percent of the resource. This percent-of-flow approach has been used to establish and implement minimum flows in numerous District systems and has been supported by multiple independent peer reviews (Flannery et al. 2002; Herrick et al. 2017; Heyl 2008; Heyl et al. 2010, 2012; Leeper et al. 2012).

The basis for the management decision to equate a 15 percent change to significant harm lies, in part, with a recommendation put forth by the peer-review panel that considered the District's proposed minimum flows for the upper Peace River. In their report, the panelists note that "*In general, instream flow analysts consider a loss of more than 15 percent habitat, as compared to undisturbed or current conditions, to be a significant impact on that population or assemblage*" (Gore et al. 2002). The panel's assertion was based on consideration of environmental flow studies employing the Physical Habitat Simulation Model (PHABSIM) for analyzing flow, water depth and substrate preferences to quantify aquatic species habitat availability.

Use of a 15 percent change in habitat or resources as constituting significant harm and therefore, for development of minimum flow recommendations, has been extended by the District to evaluate changes beyond the original instream habitat (PHABSIM) application. Because the ecological integrity of a river depends upon diverse factors including salinity, temperature, and other measurable variables, the 15 percent standard has been used to identify significant harm as the loss or reduction of: habitat associated with invertebrates and fish in freshwater and estuarine systems; days and spatial extent of floodplain inundation; population size or abundance of fish and invertebrates; temperature-based habitats for the Florida manatee (*Trichechus manatus latirostris*); and salinity-based habitats in estuaries. The determination of significant harm as the loss of 15% of these and other ecological criteria linked to environmental values has been incorporated into numerous minimum flows included in the District's Water Levels and Rates of Flow Rule.

Nineteen peer review panels have evaluated the District's use of the 15 percent standard for significant harm. Although many have questioned its use, none have identified a more appropriate industry standard or best practice for environmental flows management.

Environmental flows, of which minimum flows may be considered a subset, have been studied worldwide. Many systems that have received attention are much more heavily altered than those within the District. For example, the published research on environmental flows includes systems that have withdrawals in excess of 50 percent, impoundments, or both, for example Murray-Darling in Australia (Overton et al. 2009), San Francisco Bay (Kimmerer 2002), and many more reviewed by Poff and Zimmerman (2010). Two independent reviews of existing literature both concluded that although the majority of studies (86% - 92%) recorded ecological changes in response to reduced flow, there are no universal responses that can be used to confidently apply presumptive, flow-based thresholds for harm across systems (Lloyd et al. 2004; Poff and Zimmerman 2010). In their literature review, Lloyd et al. (2004) conclude that across rivers, relationships between flow and ecological responses are not simple, and no simple thresholds were detected. In order to apply presumptive, flow-based criteria, we would need to be able to assume simple relationships between flow and ecological responses, which Lloyd et al. (2004) found do not exist across rivers. Poff and Zimmerman (2010) reviewed 165 papers and found "strong and variable ecological responses to all types of flow alteration." A presumptive, habitat- or resource-based standard for significant harm avoids the assumption of simple, consistent relationships between flow and ecological responses by using available data to predict changes in incremental flow reductions when natural thresholds either do not exist or are not represented by the current, best information available.

Potential loss of habitats and resources in other systems has been managed using methods other than the 15 percent resource reduction standard. In some cases, resources have been protected less conservatively: habitat loss > 30 percent compared with historical flows (Jowett 1993) and preventing > 20 percent reduction to historical commercial fisheries harvests (Powell et al. 2002). Dunbar et al. (1998) note, "…*an alternative approach is to select the flow giving the 80 percent habitat exceedance percentile*," which is equivalent to an allowable 20 percent decrease from baseline conditions. More recently, the Nature Conservancy proposed that in cases where harm to habitat and resources is not quantified, presumptive standards of 10 percent to 20 percent reduction in natural flows will provide high to moderate levels of protection, respectively (Richter et al. 2011). More recently, Gleeson and Richter (2017) suggest that "high levels of ecological protection will be provided if groundwater pumping decreases monthly natural baseflow by less than 10% through time." Presumptive flow-based criteria such as these assume that resources are protected when more detailed relationships between flow and resources of interest are not available. Habitat- or resource-based presumptions of harm are based on data and analyses linking incremental reductions in flow to reductions in resources or habitats. As such, the 15% habitat- or resource-based standard makes more use of the best information available than a presumptive, flow-based criterion would. In the absence of natural breakpoints, inflections, or thresholds, the 15% presumptive habitat or resource-based standard for significant harm represents the District's use of the best available information.

1.4.2 Flow Definitions

To address all relevant requirements of the legal mandates described above and aid in the understanding of information presented in this report, we find it helpful to elaborate on several flow-related definitions and concepts.

1. Flow refers to streamflow or discharge – the volume of water flowing past a point for a given unit of time.
2. Long-term is defined in Rule 40D-8.021, F.A.C., as an evaluation period for establishing minimum flows and levels that spans the range of hydrologic conditions which can be expected to occur based upon historical records.
3. Reported, measured, gaged, and observed flows can be directly measured, however, in practice, flows are derived from relationships to directly-measured stage (elevation) and velocity data. The U.S. Geological Survey (USGS) commonly employ an index velocity approach, which uses acoustically measured velocity and cross-sectional area to calculate discharge for reported flows in tidal rivers and their contributing springs. Use of regression equations relating water levels in groundwater to surface water levels near the spring vent has also been used by the USGS for these systems (Knochenmus and Yobbi 2001).
4. Modeled flows are flows that are derived using a variety of modeling approaches. Examples include flows predicted using numerical flow models, flows predicted with statistical models derived from either observed or other modeled hydrologic data, and impacted flows adjusted for withdrawal-related flow increases or decreases.
5. Impacted flows are flows that include withdrawal-related impacts. Impacted flows can be *reported flows*, and they can also be *modeled flows*.
6. Unimpacted, baseline, or historic(al) flows occurred in the absence of withdrawal impacts. Unimpacted flows may be *observed flows* if data exists prior to any withdrawal impacts. More typically, unimpacted flows are long-term flows adjusted for withdrawals and/or other alterations. Rule 40D-8.021, F.A.C., defines “historic” as “a Long-term period when there are no measurable impacts due to withdrawals and Structural Alterations are similar to current conditions.”
7. Minimum flow is defined by the Florida Water Resources Act of 1972 as “the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area.”
8. A hydrologic (flow) regime is the overall pattern in the quantity, timing and variation of flows in a river. Rule 62-40.473, F.A.C., dictates that “minimum flows and levels should be expressed as multiple flows or levels defining a minimum hydrologic regime, to the extent practical and necessary to establish the limit beyond which further withdrawals would be significantly harmful as provided in Section 373.042(1), F.S.” The emphasis on a flow regime, rather than a single minimum flow value, reflects the natural variation present in flowing water systems (Poff et al. 1997). Expressing a minimum flow as an allowable percentage of a flow addresses the intent of protecting the flow regime as allowable flow changes are proportionally-scaled to the magnitude of flow.

1.4.3 Adaptive Management

This reevaluation of minimum flows in the Homosassa River System reflects the application of an adaptive management strategy for dealing with uncertainty in this complex, dynamic system. Uncertainty is an unavoidable consequence of the ever-changing natural and anthropogenic processes within and affecting the Homosassa River System. From both scientific and management perspectives, there is uncertainty associated with determining withdrawal impacts on physical, biological, and chemical aspects of the system.

Adaptive management is a standard approach for reducing the inherent uncertainty associated with natural resource management (Williams and Brown 2014) and is recommended by the U.S. Department of the Interior for decision making in the face of uncertainty about management impacts (Williams et al. 2009). Adaptive management is a systematic, iterative approach to meeting management objectives in the face of uncertainty through continued monitoring and refinement of management actions based on consideration of alternatives and stakeholder input.

The initial evaluation (Leeper et al. 2012) and rulemaking that resulted in establishment of the existing minimum flows for the Homosassa River System in 2013 were completed using the best information and the most accurate tools available for predicting withdrawal impacts. However, as with all natural systems management, there was uncertainty associated with the initial recommended minimum flows, and this uncertainty was one of the factors contributing to the scheduling of a reevaluation of the system in 2019. Between development of the initial minimum flow recommendation and this 2019 reevaluation, the District has continued monitoring the system (including collection of data on fish, plants, invertebrates, water quality, water flows and levels), evaluated withdrawals that may affect the system, and has updated the most accurate tools for predicting withdrawal impacts on this system. In addition to supporting this 2019 reevaluation, the newly developed information has been used for annual status assessments which have indicated the established minimum flows continue to be met.

This 2019 reevaluation of minimum flows closes the loop for a single iteration of an adaptive management process by assembling, evaluating and using the best information currently available to develop revised, recommended minimum flows for the Homosassa River System. The minimum flow recommendations resulting from this reevaluation are made in acknowledgment of the continued, unavoidable uncertainty in our understanding of natural patterns and processes inherent to the system as well as uncertainty associated with predicting the consequences of future water withdrawals. Continued adaptive management of the Homosassa River System will require ongoing monitoring, assessment, and periodic reevaluation of minimum flows.

1.5 Differences Between Original Minimum Flow Evaluation and this 2019 Reevaluation

This report documents a 2019 reevaluation of the current minimum flows established in 2013 for the Homosassa River System, and the original, technical information summarized by Leeper et al. (2012) that supported that effort. Much of the technical data, analyses, methodologies, models and assumptions described in the 2012 District report also support the current minimum flow reevaluation; however, the reevaluation effort includes substantial updates of this information. Important updates for the reevaluation include:

1) **Surface water modeling improvements:** The Laterally Averaged Model for Estuaries (LAMFE) model replaces the Environmental Fluid Dynamics Code (EFDC) model and empirical salinity regressions. With similar grid resolution, the LAMFE model fits the river bathymetry better than the EFDC model does for the Homosassa River, which is narrow and meandering. Because of the narrowness, cross-sectional variations are much smaller than those in the longitudinal and vertical directions in the Homosassa River and a laterally averaged hydrodynamic model such as the LAMFE model is suitable for the riverine estuary. The LAMFE application to the Homosassa River in this minimum flows re-evaluation has much longer periods for calibration, verification, and model runs than the previous evaluation using the EFDC model and empirical regressions (Table 1-1). LAMFE model verification statistics represent an improvement of the 2012 EFDC model and regression models. In the initial evaluation in 2012, the model boundary excluded upstream areas of low salinity habitats. Salinities ≤ 2 psu were found to be most sensitive in the Homosassa River in that initial evaluation, but they were not used to set minimum flows because of the restricted boundary. This has been fixed in this reevaluation effort. Empirical regressions from 2012 are fully replaced by LAMFE in 2019. The LAMFE surface water modeling effort is described in Chapter 6.

2) **Newer, more extensive data:** The 2012 report used data on water levels, flows, water quality, and biological assessments collected prior to 2010. The 2019 reevaluation used more recent and comprehensive data. Water level, conductance, and temperature data were measured in Mason Creek and Salt River to better specify boundary conditions for the LAMFE model. Updated USGS gage data for previously assessed sites are summarized in Chapter 2 of this report. The latest water quality information includes data collected by the District's Data Collection Bureau. The District analyzed these and other water quality data to look for links between water quality and flow. This information is provided in Chapter 3.

3) **Biological status and trends updated:** The district conducted new, more thorough mapping of shoreline and submerged aquatic vegetation (SAV), surveyed oysters and barnacles, and cooperated with the Florida Fish and Wildlife Conservation Commission (FWC) to conduct seasonal fish community surveys. This information is provided in Chapter 4.

4) **Groundwater modeling improvements:** The hydrogeologic model used to predict effects of groundwater withdrawals on river and spring flows has been updated (current version is the Northern District Model, Version 5 or NDM5). New hydrological and water use data that have become available since the 2012 evaluation have been incorporated into model development and simulations. These updates are described in Chapter 5.

The District's 2019 reevaluation of the currently established minimum flows for the Homosassa River System represents a complete, new evaluation with new, expanded data sets, updated models and other analytical tools. The data, modeling and other analytical updates are responsible for differences in conclusions between the previous 2012 evaluation and the current 2019 reevaluation. This report is a summary of the most recent data and analyses; it is not a revision of the previous 2012 report. This report does not follow the same chapter and heading structure from the previous 2012 report, but all elements found in the 2012 report can be found in this newer 2019 reevaluation report (Table 1-2).

Table 1-1. Updates to surface water modeling for the Homosassa River System minimum flow reevaluation. EFDC = Environmental Fluids Dynamic Code; LAMFE = Laterally Averaged Model for Estuaries.

Model	Calibration	Verification	Scenarios
2012 EFDC	2006-09-15 to 2006-12-31 (>3 mo)	2007-01-01 to 2007-06-30 (7 mo)	2007-01-01 to 2007-12-01 (12 mo) for Salinity 2007-10-01 to 2008-03-31 (6 mo) for Temperature
2019 LAMFE	(2014-11-04 to 2016-05-30) (> 18 mo)	2016-06-01 to 2017-08-31) (15 mo)	2007-10-09 to 2018-03-12 (10 y, 5 mo)

Table 1-2. Updates of the 2012 Homosassa River System minimum flows report included in this report on the 2019 minimum flows reevaluation.

2012 Report Section	Updates Included in this 2019 Report
1.1 – 1.3	**All introductory material in new Chapter 1**
2.1 Location and general description, 2.2 Physiography and watershed, 2.3 Land Use and Cover, 2.6 Bottom substrates	**Chapter 2. New figures of watershed and springshed. Land use and cover updated.**
2.4. Hydrology	**Moved to hydrologic evaluation Chapter 5**
2.5 Bathymetry and River Kilometer	**Moved to surface water modeling in LAMFE Chapter 6**
2.7 Shoreline	**Shoreline vegetation mapping evaluated in Chapter 4**
2.8 Water quality	**New analysis of water quality in Chapter 3.**
3.1 Vegetation, 3.2 Benthic Macroinvertebrates, 3.3 Fish and Invertebrate Plankton and Nekton, 3.4 Manatees	**Chapter 4 Biological Status and Trends includes new data on shoreline vegetation mapping, new SAV data and analysis, new fish community assessment, and new manatee evaluation.**
Chapter 4 Resources of Concern, Chapter 5 Results and Initial Recommendation	**Information has been reorganized. Status and trends of biological information in now found in Chapter 4. Factors evaluated for quantitative determination of minimum flows discussed in Chapter 7.**
Chapter 6 Peer Review and Stakeholder Comments	**Included as part of Chapter 7 Minimum Flows Recommendation**
Chapter 7 Results of Additional Analysis	**TBD: following peer review and public comment, additional chapters may be added.**

CHAPTER 2 - PHYSICAL SETTING AND DESCRIPTION OF THE HOMOSASSA RIVER SYSTEM

The Homosassa River System includes several named rivers and creeks, surface drainage basins, a spring group consisting of many individual spring vents, and an associated springshed (Figure 2-1). Rule 40D-8.041(16) adopted in 2013 states the Homosassa River System includes the watercourse from the Homosassa Main Springs Complex to the Gulf of Mexico, including the southeast fork of the Homosassa River, Halls River, Hidden River and all named and unnamed springs that discharge to these rivers. This description is applicable for the current minimum flows reevaluation for the system, which can alternatively be referred to as the Homosassa River / Homosassa Spring Group.

The Homosassa River and its contributing spring vents are located within Citrus County, while the springshed spans portions of Citrus and Hernando Counties (Figure 2-2). Both Citrus and Hernando Counties are entirely within the boundaries of the District. The Homosassa River and its springshed is one of five first-magnitude springs systems that define the Springs Coast region. Listed from north to south these springs systems are: Rainbow, Crystal River/Kings Bay, Homosassa, Chassahowitzka, and Weeki Wachee.

White (1970) places the Homosassa Group springshed across five physiographic regions (Figure 2-3). The District (Jones et al. 2011, Champion and Starks 2001) and others (Knochenmus and Yobbi 2001) have used the physiographic regions of White (1970) to describe the physiography of its springsheds in past reports. The Drowned Karst region extends offshore from the mouth to shallow depths (less than 20 feet) and is brackish due to freshwater discharge from springs. The Homosassa River runs through the Coastal Swamps region, characterized by wetlands where poorly drained, saturated organic soils overlie carbonate rocks of the Upper Floridan aquifer. Recharge is variably low to nonexistent in the Coastal Swamps province (Jones et al. 2011). The springs and upper portion of the river are located in the Gulf Coastal Lowlands region which consists of scarps and terraces that create rolling hills capped by aeolian sands. The Gulf Coastal Lowlands experience moderate to high recharge (Jones et al. 2011). The springshed extends into the Brooksville Ridge, characterized by rolling hills that consist of remnant marine deposits modified by subaerial erosion, karstification, and wave action. Recharge in the Brooksville Ridge area is highest because it is a karst terrain with internal drainage to the upper Floridan aquifer (Kimrey and Anderson 1987). The most inland portion of the springshed is in the Tsala Apopka Plain, which contains interconnected lakes and islands hydraulically connected to the Upper Floridan aquifer. Recharge within the Tsala Apopka Plain is low due to the diminished downward vertical gradient between surface waters or surficial aquifer and the Floridan aquifer (Rutledge 1977).

Surface water contributions to the Homosassa River come from the Homosassa River drainage basin (HUC 03100207) of the Upper Coastal Areas watershed (Figure 2-4). The drainage basin or watershed extends over approximately 56 square miles in Citrus County. The Homosassa, Southeast Fork of the Homosassa and Halls rivers lie within the Homosassa River Drainage Basin. Hidden River is located in the Direct Runoff to Gulf drainage basin to the south of the Homosassa River basin. The Salt river extends to the direct runoff and Crystal River basins to the north. To the south, the Hidden River is within the Direct Runoff to Gulf drainage basin, an area that includes approximately 61 square miles of Citrus County. There is little surface runoff in these basins, and only a small portion of the rainfall makes its way directly to the channels of the Homosassa, Southeast Fork, Halls and Hidden Rivers without first infiltrating into the aquifer.

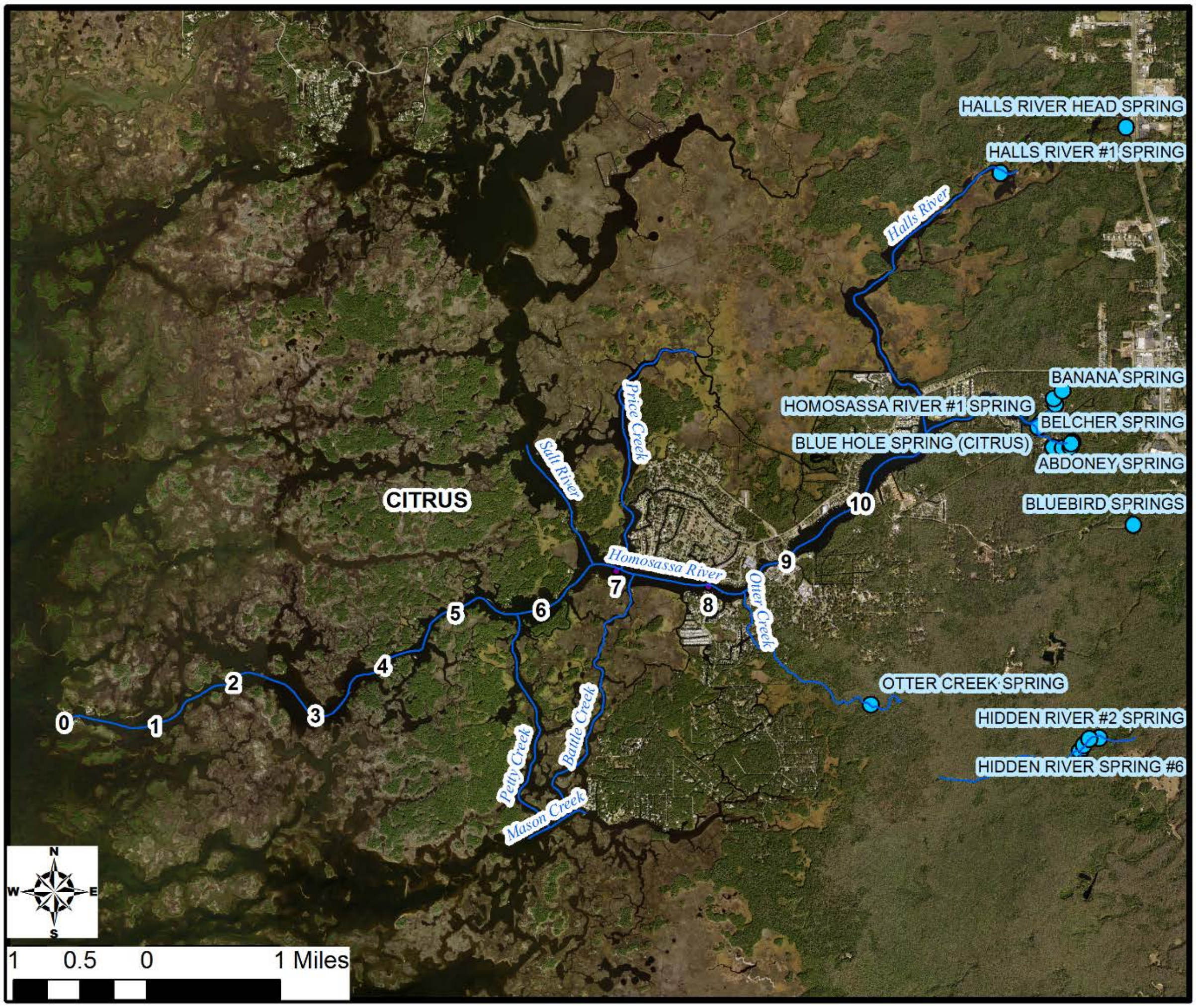


Figure 2-1. Homosassa River System river segments and springs.

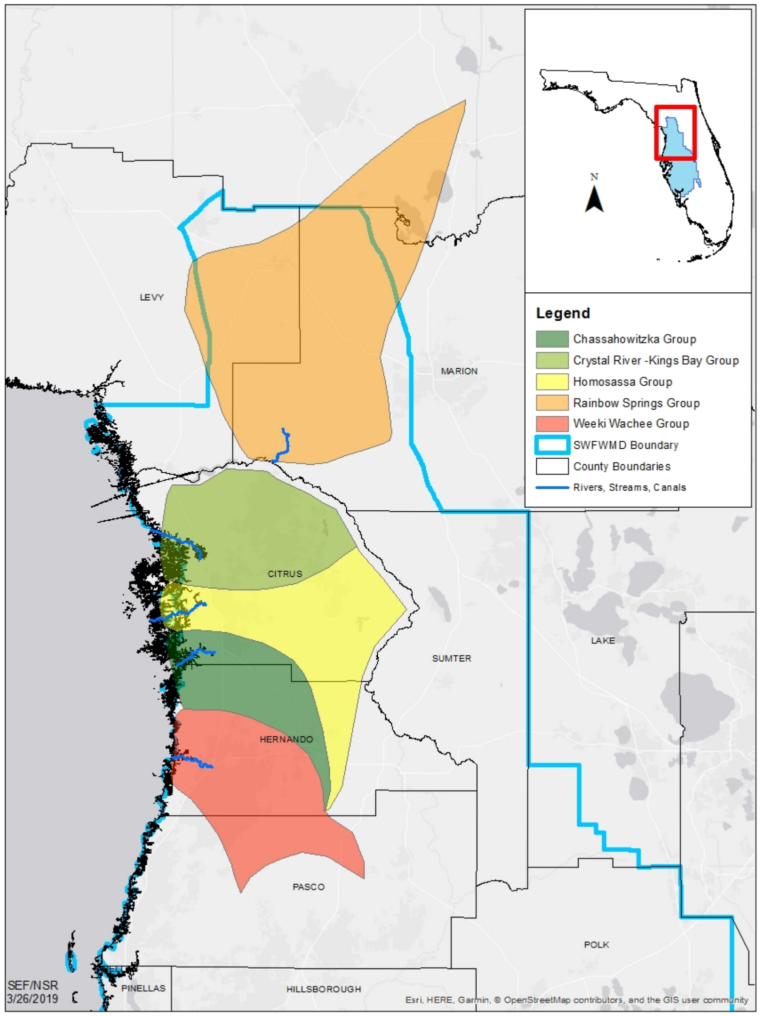


Figure 2-2. Five first-magnitude springs systems are located within the Southwest Florida Water Management District. Inset shows extent of springs coast within state of Florida and District boundary. Rivers (blue lines) are relatively small compared with springsheds (shaded areas).

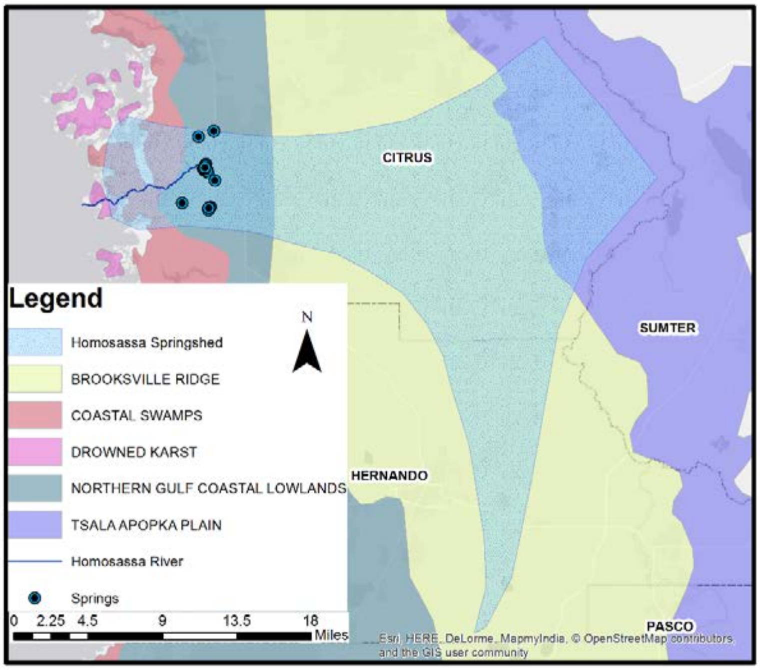


Figure 2-3. The Homosassa Group springshed spans five physiographic regions described by White (1970).

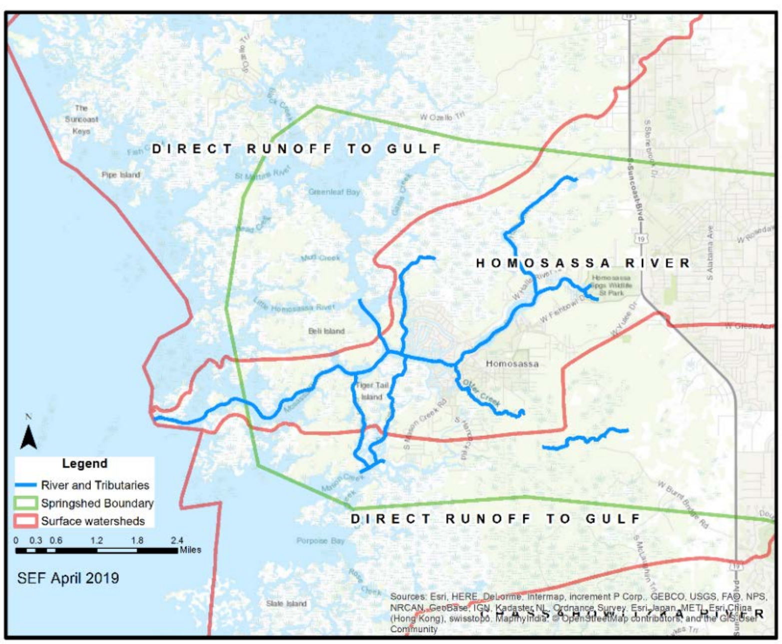
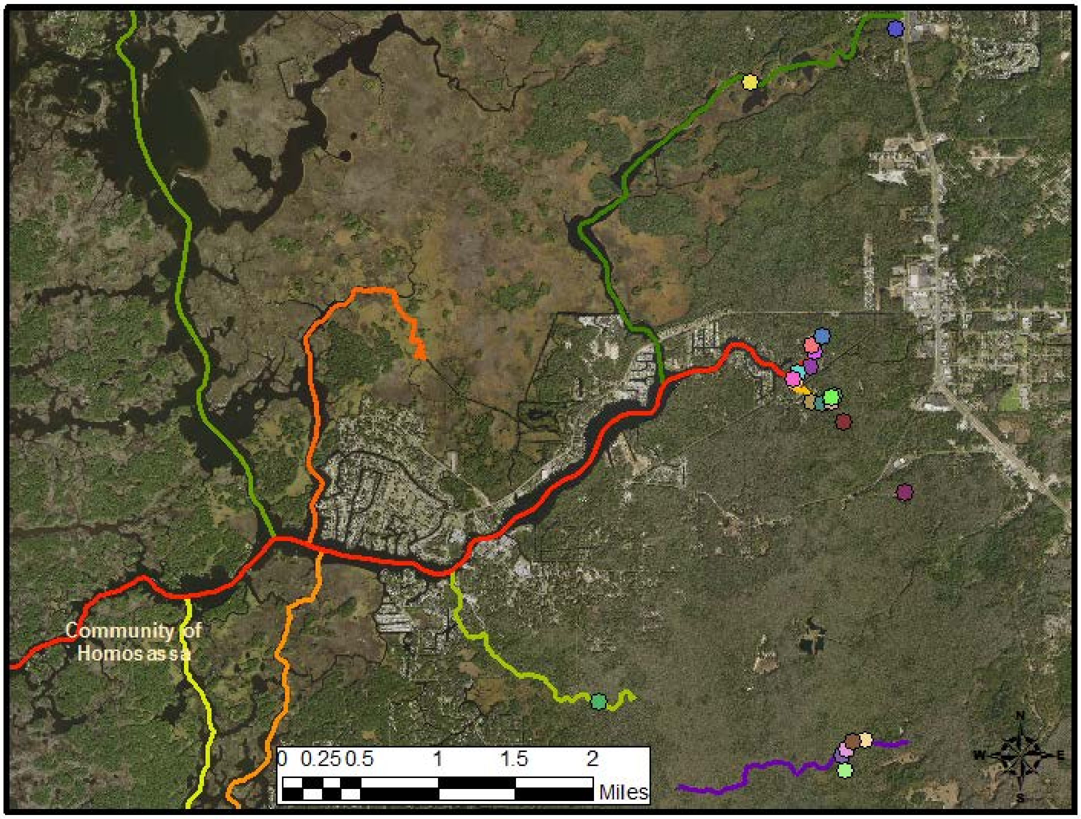


Figure 2-4. The Homosassa River and its tributaries intersect three surface watersheds (basins).

2.1 Location and Description of Channels and Springs

The Homosassa River System includes numerous river segments, tributaries and springs (Figure 2-1). River segments with Geographic Names Information System (GNIS) names identified in the District Spring.lyr data edited in 2014-2015 include the Homosassa River, Southeast Fork, Halls River, Hidden River, Price Creek, Battle Creek and Petty Creek. The Homosassa River system is fed by 24 named springs included in the District Springs.lyr data layer edited in 2014-2015 (Figure 2-5).

The Homosassa River flows approximately 8 miles to its mouth near Shell Island in the Homosassa Bay region of the Gulf of Mexico. Yobbi and Knochenmus (1989) report that the Homosassa River is approximately 200-700 feet wide and 5 feet deep in the upstream reach and about 1,000 feet wide and 15 to 20 feet deep at the mouth. Artificial channels associated with drainage and access improvement are common in the upper half of the river. The lower portion of the river is connected to a number of tidal creeks and bayous, including Price Creek, Salt River, Sam's Bayou and False Channel to the north and Otter Creek, Battle Creek and Petty Creek to the south. All water bodies in the Homosassa River System are classified as Outstanding Florida Waters, a designation associated with Florida's anti-degradation policy (Rule 62-302.700, F.A.C.).



ABDONEY SPRING	HIDDEN RIVER SPRING #7
ALLIGATOR SPRING (CITRUS)	HIDDEN RIVER SPRING #8
BANANA SPRING	HOMOSASSA #1 SPRING
BEAR SPRING (CITRUS)	HOMOSASSA #2 SPRING
BELCHER SPRING	HOMOSASSA #3 SPRING
BLUE HOLE SPRING (CITRUS)	HOMOSASSA RIVER #1 SPRING
BLUEBIRD SPRINGS	MCCLAIN SPRING
HALLS RIVER #1 SPRING	OTTER CREEK SPRING
HALLS RIVER HEAD SPRING	PUMPHOUSE SPRING
HIDDEN RIVER #2 SPRING	SOUTHEAST FORK HEADSPRING HOMOSASSA
HIDDEN RIVER HEAD SPRING	TROTTER #1 SPRING
HIDDEN RIVER SPRING #6	TROTTER MAIN SPRING
	GARVIN SPRING

Figure 2-5. Named springs of the Homosassa River system. Springs from Springs.lyr. River segments from Named Hydrographic features.lyr with the SE Fork identified separately by District Staff.

2.1.1 Three Upstream Reaches

There are three upstream reaches, identified here as Fishbowl, Wildlife, and Confluence, of the main stem of the Homosassa River above or near the confluence with the Southeast Fork of the Homosassa River (Figure 2-6). This document is the first to give these names to these reaches, and it is done for the purpose of categorizing the numerous springs and the recognition that the Wildlife reach is on a distinct spring run which acts as a tributary to the main stem of the Homosassa River.

2.1.1.1 Fishbowl Reach

The Fishbowl reach includes Homosassa Springs 1, 2, and 3 and. also includes the USGS Homosassa Springs at Homosassa Spring, FL Gage (No. 02310678), discussed below in section 2.3). Homosassa Springs 1, 2, and 3 share a spring pool beneath the “fishbowl”, an underwater viewing platform within the Ellie Schiller Homosassa Springs Wildlife State Park (Figure 2-7). The pool surrounding these three vents is 189 ft north to south and 285 ft east to west (Scott et al. 2004). Depth of these vents is 67, 65, and 62 ft, respectively. These three vents are located within a collapsed cavern which beyond 70 ft deep becomes too narrow for divers to further safely explore (Karst Environmental Services 1992) (Figure 2-8). Water quality of the three main vents changes significantly over a tidal cycle. The spring as a whole discharges brackish water (1000 – 10,000 mg/L total dissolved solids) during low tide (Jones et al. 2011). Water quality varies among these three vents, with vent 3 discharging the freshest water of the three (Champion and Starks 2001).

2.1.1.2 Wildlife Reach

The Wildlife reach includes three springs (Alligator, Banana, and Bear) found within or near wildlife enclosures of the state park (Figure 2-6). The run originates at Bear Spring, which is located just outside the black bear enclosure within the park. The Bear Spring Pool is approximately 60 ft. long by 20 ft. wide and 5 ft deep with two vents, one in the northern and one in the eastern sections of the pool (Scott et al. 2004). Banana Spring discharges into a man-made pool measuring 60 ft. by 40 ft and empties into a spring run that flows under a foot bridge and into Alligator Spring. Downstream, Alligator Spring lies within a larger, 100 by 150 foot pool with an approximate depth between 5 and 8 feet. The Wildlife Reach runs approximately 1000 feet total from Bear Spring to the confluence with the main stem of the Homosassa River at the Fishbowl reach (Figure 2-6).

2.1.1.3 Confluence Reach

The Confluence reach includes Homosassa River #1 spring, Blue Hole spring, and Garvin spring, which was identified in the 2012 report as Homosassa unnamed spring #2 (Leeper et al. 2012) (Figure 2-6). Homosassa River # 1 Spring is the location for quarterly grab sample monitoring by the District’s Water Management Information System (WMIS) (WMIS Site ID 20990) (28.7992 N, 82.5883 W). Jones et al. (2011) state that Homosassa River #1 spring is located just off the north shore of the Homosassa River, and is in a shallow depression approximately 50 feet across and 10 feet deep. The actual vent of the spring is small, very little flow is discernable near the vent, and there is no evidence of a boil or slick on the surface. Scott et al. (2004) calls this spring “Homosassa Unnamed Spring No.1”.

Blue Hole Spring is located within the Homosassa Springs Wildlife State Park, west of the education center, on the south side of the Homosassa River. The spring occupies a 75 ft by 25 ft cove with exposed limestone surrounding a 15 ft deep vent (Scott et al. 2004).

Garvin Spring (WMIS Site No. 889629) is a vent newly added to WMIS. This spring was identified as “Homosassa Un-named Spring #2” in the 2012 minimum flows report. It was subsequently removed from District “springs” layer and has now been added as a WQMP grab sampling location. This spring is located in a cove off the east shore of the Southeast Fork of the Homosassa River. Scott et *al.* (2004) note that the spring pool is approximately 25 feet in diameter with a depth of about 3.1 feet. Garvin spring is described in WMIS as a small pool under the tree canopy with a short run to the Homosassa River. The spring is accessible by land on the south end of the park. A small pavilion is adjacent to the pool. Grab samples for water quality analyses are collected quarterly. This site will add additional data to the Homosassa Springs Group for monitoring water quality concerns associated with high nutrient concentrations in the Upper Floridan aquifer.

2.1.2 Southeast Fork of the Homosassa River

The Southeast Fork of the Homosassa River originates from several spring vents and extends approximately 1200 ft to the bridge at West Fishbowl Drive and another 400 feet downstream to its confluence with the Homosassa River (Figure 2-9). The Southeast Fork is a shallow, narrow system, typically less than 100 feet in width in most areas. Abdoney, Belcher, McClain, Pumphouse, Trotter #1, and Trotter Main springs contribute an average discharge of 69.1 cfs from 89 measurements taken between 1931-1974 (Champion and Starks 2001). Jones et al. (2011) report that Southeast Fork springs always discharge fresh water, and water quality does not change over a tidal cycle.

The southeast fork headspring is found 785 ft southeast of Trotter #1 spring and contributes to a stream that runs approximately 500 ft before sinking and reemerges as Trotter Main, Trotter #1 and possibly Pumphouse springs, which often become tannic after heavy rainfall due to the surface run (Jones et al. 2011).

Pumphouse spring is at the head of a cove on the south side of a tributary to the river. Pumphouse spring pool is 15 feet to 20 feet in diameter and averages 3 feet deep (Scott et al. 2004). Trotter Main Spring issues from a 2 ft long limestone fissure in 10 feet of water (Scott et al. 2004). Bridger et al. (2014) refer to the location of springs in the Southeast Fork as “Spring Cove”.

2.1.3 Halls River

Halls River originates with the Halls River Head Spring and flows approximately 2.5 miles to its confluence with the Homosassa River (Figure 2-10). The Head Spring pool is circular, 200 feet wide, and contains a few sand boils but no visible surface boil (Champion and Starks 2001, Jones et al. 2011). Scott et al. (2004) place the Halls River #2 Spring approximately 900 feet down the head spring run, discharging from a 1.5 ft diameter opening in limestone and creating a spring pool measuring 40 ft north to south and 30 ft east to west. Several additional small sand boils issue from the Halls River #2 Spring pool bottom of soft sand and detritus. The spring water is clear. Emergent and submerged vegetation (SAV) are abundant along the spring run. Combined flow from Hall's River Head Spring and Hall's River #2 Spring travels west approximately 300 ft through a 2 ft deep, 8 ft wide spring run that enters the uppermost portion of Halls River from the east. The Halls River #1 Spring is located approximately 0.7 miles downstream from the Halls River #2 Spring. In addition to the three named springs above, flow in the 2.5 mile-long Halls River is derived from many uncharted springs in the wide, shallow, and thickly vegetated river channel (Knochenmus and Yobbi 2001). The lower portion of the river is consistently broader, ranging between 200 and 750 feet in width.

2.1.4 Hidden River

Hidden River runs parallel to and approximately 2.5 miles to the south of the Homosassa (Figure 2-5). As defined by the National Hydrography Dataset, the Hidden river runs 1.6 miles, although Jones et al (2011) and Knochenmus and Yobbi (2001) indicate the river is 2 miles in length.

The names and locations of springs in the Hidden River are not consistent across sources (Table 2-1). For example, there are two sites with Head springs – one identified by the District, the other by the USGS. Furthermore, the District and the USGS identify the same spring at 28°46'03" N, 82°35'07" W, but the USGS names this "Hidden River Spring 6", while the District identifies it as "Hidden River Spring #8". In addition, the District has identified 4 springs not identified by the USGS.

Various reports have identified and named spring vents in the Hidden River. The District has identified 5 spring vents contributing flow to the Hidden River in its Springs.lyr layer file (Figure 2-11). Jones et al. (2011) identifies two springs, the Hidden River Head Spring and Hidden River Spring #2, which correspond to data collection sites in the District's Water Management Information System. According to Knochenmus and Yobbi (2001), two springs contribute flow to Hidden River: Hidden River Head Spring and Hidden River Spring number 6, and both are shallow (about 5 feet deep) with small sediment filled vents. The two springs identified in Knochenmus and Yobbi (2001) are found in the USGS National Water Information System (NWIS) (USGS 2018).

The USGS places the Hidden River Head Spring near Homosassa, FL (No. 284607082344500) at 28°46'07" N, 82°34'45" W (Table 2-1). Note that the USGS numbering for springs is based on latitude and longitude. The USGS Head Spring location coincides with the NHD flow line origin, while the District Head Spring site is 0.27 miles (435 meters) further downstream. The USGS reports Field/Lab water-quality samples from 1988-06-01 at this site as reported in Yobbi (1992). Knochenmus and Yobbi (2001) describe the Hidden River Head Spring and Hidden River Spring number 6 as shallow (about 5 ft deep) with small sediment-filled vents.

The District's Water Management Information System places the Hidden River Head Spring (WMIS Site No. 21043) at 28°46'07.36" N, 82°34'59.69" W (Table 2-1, Figure 2-11). This is identical to the location and name in the District's Springs.lyr GIS layer file. In a District report, Jones et al. (2011) refer to the District Head Spring site, and this is the site where District water quality sampling takes place. Jones et al. (2011) note that the District Head Spring is approximately four feet below the water surface in a small circular depression five feet in diameter. There does not appear to be a significant change in water quality over a tidal cycle. A field trip by District Staff in August 2017 identified this location as the furthest upstream location navigable by kayak, but also noted that the stream continued in the direction of the USGS Head Spring (No. 284607082344500). The District has an active sampling program at this site.

Hidden River #2 Spring is named "Hidden River 2 Spring" (no pound sign) in WMIS and is located consistently by WMIS and Springs.lyr at 28°46'07.01" N, 82°35'03.63" W. This spring is labeled "District Spring #2" in Figure 2-11. This is the second of two springs identified by Jones et al. (2011). This spring does not correspond with either of the two springs identified by the USGS (2018). Jones et al. (2011) note that this spring is located a few hundred feet downstream of the head spring and is configured very similar to the head spring.

USGS Hidden River Spring 6 near Homosassa, FL (No. 284603082350700) is referred to as "Hidden River Spring Number 6" in Knochenmus and Yobbi (2001) and located at 28°46'03" N, 82°35'07" W. The District's nearest spring in its Springs.lyr places Hidden River Spring #8 at the same location, but reports to the third decimal second in WMIS, whereas USGS NWIS Web reports only whole decimal-degree-seconds.

District springs #6 and #7 are not mentioned in Jones et al. (2011), Knochenmus and Yobbi (2001) or any other reports of which District Staff are aware but are identified in its Springs.lyr and have been observed by District Staff.

2.1.5 Otter Creek

Otter Creek springs is the headwaters to the Otter Creek tributary of the Homosassa River (Figure 2-1). These springs are possibly linked hydrologically to the Hidden River, which ends in a swallet, from which water is potentially transported underground until it resurfaces at the headwaters of Otter Creek (Karst Underwater Research, Inc. 2011).

2.1.6 Bluebird spring

Bluebird Springs are located approximately 0.7 miles southeast of the Homosassa Main Springs Pool in Bluebird Springs Park, which is maintained by Citrus County (Figure 2-5). Bluebird Springs has two vents. The main vent discharges into a square pool with concrete walls on three sides. This pool is connected to a larger, 225 ft by 120 ft pool. The main spring discharges through a limestone vent under about 15 feet of water in an approximate 120 by 225 foot pool (Scott *et al.* 2004). A smaller vent is approximately 150 ft east of the main vent, up a short, narrow run which converges with flow from the main vent. The spring run travels an unknown distance and is presumed to flow into the Homosassa River at an unknown point.

2.1.7 Public and Conservation Lands

Much of the land surrounding the Homosassa River and other components of the Homosassa River System is under public ownership or preserved for conservation (Figure 2-12).

The Chassahowitzka National Wildlife Refuge is owned and operated by the U.S. Fish and Wildlife Service. This refuge encompasses over 30,000 acres extending south to include the Chassahowitzka River, numerous saltwater bays, estuaries, and brackish marshes with a fringe of hardwood swamps. The Chassahowitzka National Wildlife Refuge is accessible only by boat and contains a 23,000-acre designated wilderness area.

There is a small parcel of the Crystal River National Wildlife Refuge, owned and managed by the U.S. Fish and Wildlife Service, south of Crystal River Preserve State Park, north of Chassahowitzka National Wildlife Refuge, and east of Battle creek, along a small tidal creek connecting Battle Creek to dredged channels and Homosassa River.

The 200 acre Ellie Schiller Homosassa Springs Wildlife State Park is owned by the State of Florida Trustees of the Internal Improvement Trust Fund and managed by the DEP Division of Recreation and Parks. This park includes large animal enclosures and the famous Fishbowl. Springs within or adjacent to park boundaries include Homosassa 1, 2, and 3 springs, Alligator Spring, Banana Spring, Bear Spring, Blue Hole Spring, Garvin Spring, and Homosassa River #1 Spring.

The Chassahowitzka River and Coastal Swamps area is owned and managed primarily by the District, while Citrus County manages small portion (including store, canoe launch, and campground) for public recreation at the Chassahowitzka River. This 5,679 acre area includes most of the Hidden River, as well as nearly two miles along the Chassahowitzka River and the Chassahowitzka River Springs. This area is recognized by the Florida Natural Areas Inventory as one of the largest remaining coastal hardwood swamps on the Gulf of Mexico. At the time of purchase by the District, the land cover types were assessed along with detailed descriptions of species of plants, fish, amphibians, reptiles, birds, and mammals present (Southwest Florida Water Management District 1989). The ecosystems within this sanctuary are further described in Kelly (1994).

Crystal River Preserve State Park is owned by the State of Florida Trustees of the Internal Improvement Trust Fund and managed by the DEP Division of Recreation and Parks. This extensive, 27,417 acres park encompasses shorelines and areas adjacent to Halls River, Price Creek, Salt River, Battle Creek, and areas north and south of the Homosassa River. This preserve encompasses much of the land between the Homosassa and Crystal Rivers west of U.S. Highway 19, and several sections of land north of Crystal River. Coastal lands are marine tidal marsh and swamp with hundreds of variably-sized islands in the Gulf, all of which are important for wading birds and shorebirds. The land rises to hydric hammock, upland mixed forest, scrub and sandhill.

The Withlacoochee State Forest is over 160,000 acres, and includes the Otter Creek headspring, the upper reaches of Otter Creek, Southern banks of Mason Creek, and surrounds the Districts Chassahowitzka River and Coastal Swamps area on three sides and includes the headwaters and USGS Headspring of the Hidden River.

The Yulee Sugar Mill Ruins Historic State Park is 4.7 acres and contains the ruins of a sugar mill near the Homosassa River that was once part of a thriving sugar plantation. This park is adjacent to canals that lead to the USGS Homosassa River at Homosassa, FL Gage (No. 02310700).

Bluebird Springs park is owned and operated by Citrus County and surrounds Bluebird Springs. The surrounding 5.5 acre park is developed with picnic tables, a playground and volleyball court.

The Troy Samuel Cumming Nature Preserve is a 6.1 acre site comprised of healthy bottomland hardwood hammock forest that includes hickory, southern magnolia, red bay, oaks, and cabbage palms Notable limestone rocky outcroppings occur in the preserve, providing a visual reminder of Florida's unique geology.

The Upper Coastal Mitigation Bank is a privately- owned mitigation bank managed by EarthBalance and permitted by the District. This parcel includes the Southeast Fork Headspring and run.

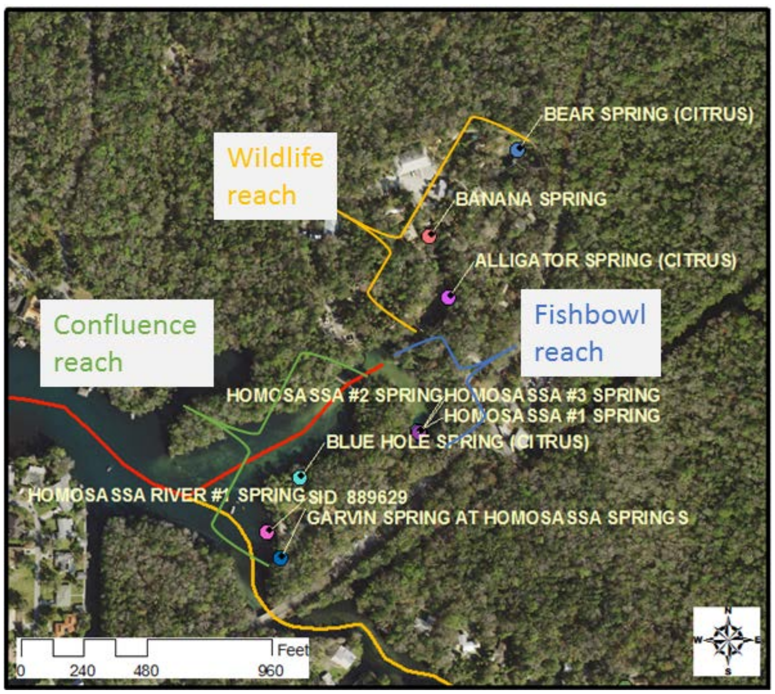


Figure 2-6. Upstream reaches of the Homosassa River. Springs from Springs.lyr. River segments from Named Hydrographic features.lyr with the SE Fork identified separately by District Staff. Garvin Spring from Active Data Collection Sites.lyr.

Figure 2-7. The “Fishbowl” at Homosassa Springs State Wildlife Park. The single pool shared by Springs No. 1, 2, and 3 is visible as the deeper, blue area in this photo. Photo credit: Joe Dube.

Figure 2-8. Homosassa Main Springs Cavern profile view. From Karst Environmental Services, Inc. (1992).

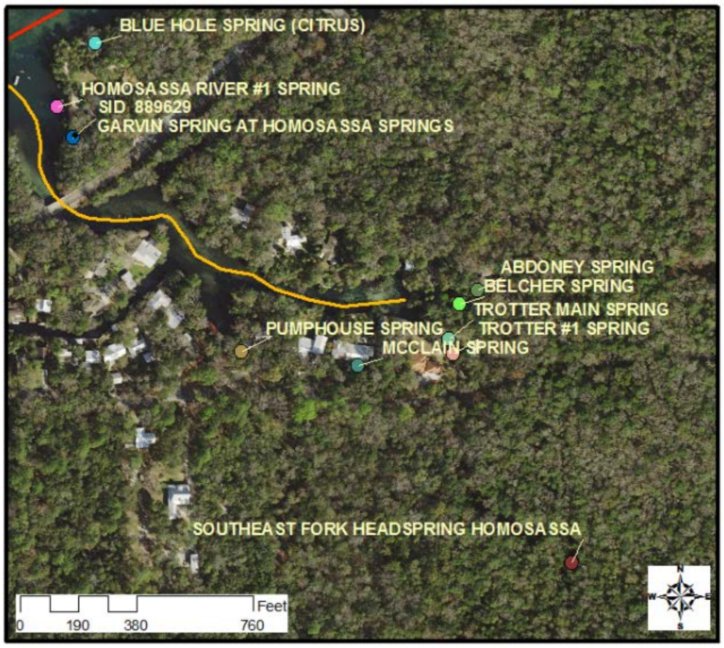


Figure 2-9. Springs on the Southeast Fork of the Homosassa River. Springs from Springs.lyr, Garvin Spring from Active Data Collection Sites.lyr.

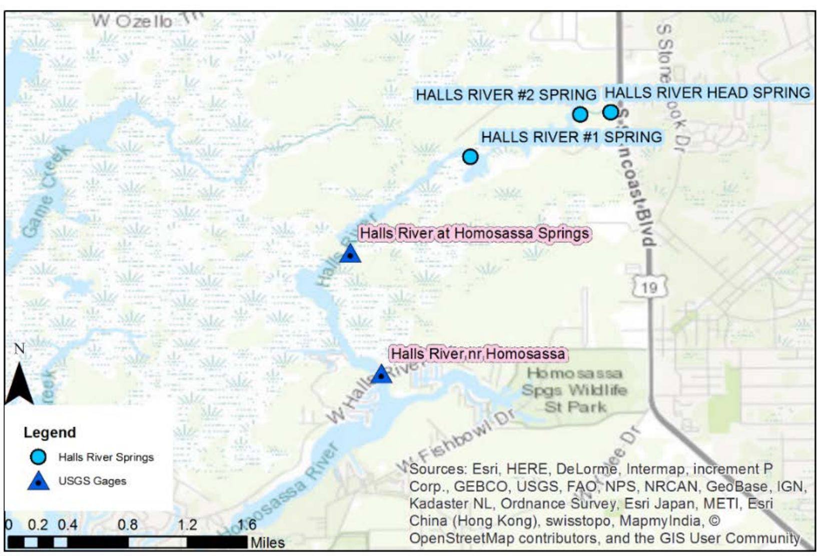


Figure 2-10. The Halls River Head Spring Halls River #1 Spring, and Halls River #2 spring contribute flows to the Halls River. Flows are gaged at the USGS Halls River at Homosassa Springs, FL Gage (No. 02310689). The USGS Halls River near Homosassa, FL gage (No. 02310690) reports temperature, gage height, and specific conductance.

Table 2-1. Springs locations in Hidden River. District sites in the District Water Management Information System (WMIS). U.S. Geological Survey sites in the USGS National Water Information System.

Name	Site Identification Number	Lat	Long
HIDDEN RIVER HEAD SPRING	WMIS No. 21043	28° 46' 07.357"	82° 34' 59.689"
USGS HEAD SPRING NEAR HOMOSASSA FL	USGS No. 284607082344500	28° 46' 07"	82° 34' 45"
HIDDEN RIVER #2 SPRING	WMIS No. 21042	28° 46' 07.01"	82° 35' 03.634"
HIDDEN RIVER SPRING #8 / HIDDEN RIVER SPRING 6	USGS No. 284603082350700	28° 46' 02.915"	82° 35' 07.133"
HIDDEN RIVER SPRING #6	None	28° 46' 04.88"	82° 35' 05.708"
HIDDEN RIVER SPRING #7	None	28° 45' 58.595"	82° 35' 06.193"

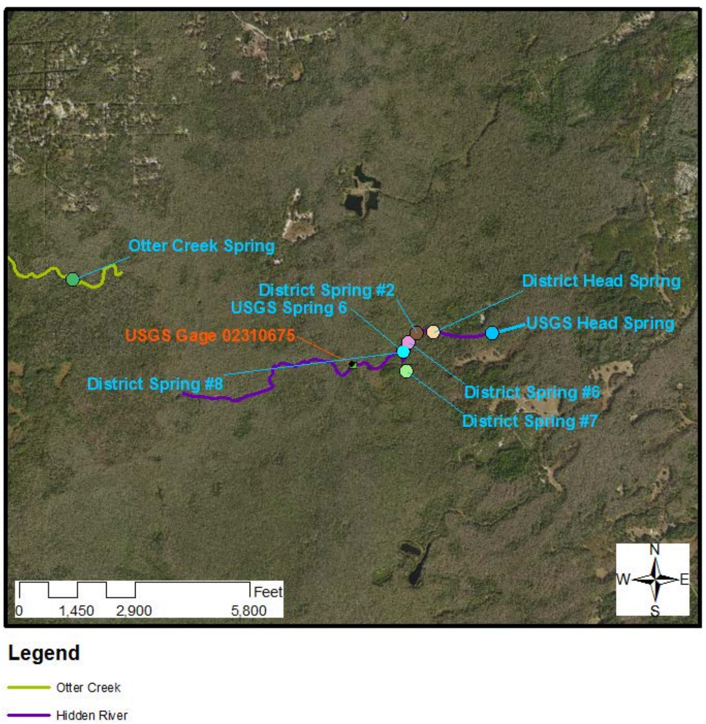


Figure 2-11. Springs of the Hidden River and Otter Creek.

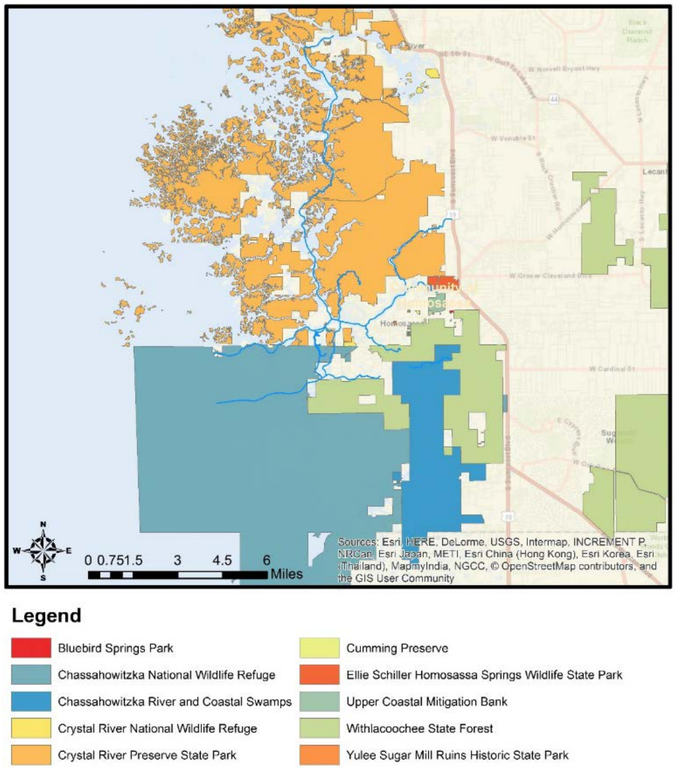


Figure 2-12. Public lands including and surrounding the Homosassa River System.

2.2 <u>Watershed Land Use and Cover</u>

Land use and cover in the Homosassa River basin of the Homosassa River System currently includes a mix of urbanized or developed lands, agricultural lands, forested uplands, wetlands and water (Figure 2-13). Based on the Florida Land Use, Cover and Forms Classification System (Florida Department of Transportation 1999), urban and built-up lands and those used for transportation, communication and utilities in 2011 accounted for 38 percent of the 35,637 acres within the Homosassa River Basin (Table 2-2). Lands classified as upland forest accounted for twenty-eight percent of the basin area and water and wetlands accounted for twenty-six percent of the landscape. Urbanized areas include the community of Homosassa and other areas adjacent to the Homosassa River, the communities of Homosassa Springs, which is located primarily east of U.S. Highway 19, and an area of Citrus County northwest of the City of Inverness.

Changes in land use and cover within the Homosassa River basin were evaluated using geographic information system layers representing land use/cover classifications for the area in 2004 through 2011. For the analyses, Esri ArcMap software was used to clip land use/cover layers to the boundaries delineated by the Homosassa River Drainage Basin. With the exception of the Urban and Built-Up and Upland Forest land use/cover classes, land use/cover in the watershed exhibited little change in the years examined between 1990 and 2011 (Table 2-1). Increases in urbanized lands have been associated primarily with decreases in forested uplands.

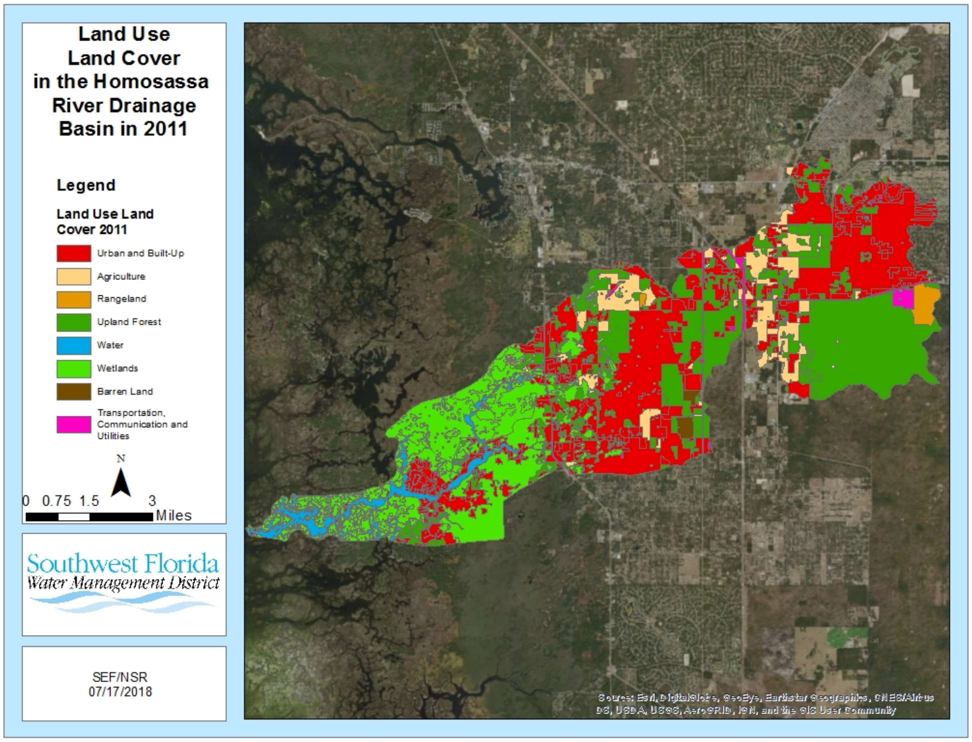


Figure 2-13. Land use–cover in the Homosassa River Drainage Basin in 2011, based on the Florida Land Use, Cover and Forms Classification System.

Table 2-2. Land use/cover by acre in the Homosassa River Drainage Basin for selected years based on Land use/cover classes of the Florida Land Use, Cover and Forms Classification System. Total area in basin is 35,637 acres.

Land Use/ Cover Class	1990	1995	1999	2004	2005	2006	2007	2008	2009	2010	2011
Urban and Built-Up	10,534	10,910	11,295	12,798	12,725	12,983	13,091	13,147	13,168	13,193	13,201
Agriculture	3,399	3,095	2,859	2,747	2,223	2,342	2,274	2,246	2,251	2,251	2,270
Rangeland	14	86	81	170	374	374	374	374	374	374	367
Upland Forest	12,089	11,954	11,646	10,176	10,377	10,107	10,046	10,002	9,974	9,971	9,967
Water	1,270	1,300	1,298	1,298	1,297	1,301	1,307	1,307	1,307	1,311	1,310
Wetlands	7,804	7,795	7,797	7,831	7,830	7,826	7,827	7,827	7,826	7,825	7,821
Barren Land	218	198	189	140	325	218	233	244	247	226	217
Transportation, Communication and Utilities	309	299	472	477	486	486	485	490	490	486	484

2.3 Gage Data

There are seven gages currently monitored in cooperation between the USGS and the District in the Homosassa River System (Figure 2-14). These gages provide the bulk of the hydrological data needed to characterize water levels, flows, salinity, and temperature throughout the system.

Periods of record differ for daily data associated with the gages (Table 2-3 A). The full records for data at these gages, including both approved and provisional data can be found at the USGS NWIS web site (USGS 2018). In addition to daily data, 15-minute data are often reported, as are field measurements and longer term values. Average values of daily data show differences among locations in flow, temperature, and salinity (Table 2-3 B).

Parameters are often recorded in different ways, for example, discharge can be calculated from regression with water levels at the gage and in nearby groundwater wells or measured through index velocity. Temperature and specific conductance are most often measured at the bottom of the water column but are also reported at middle and top of water column at some gages.

Periods of record often differ for parameters within a gage site and differ among gage sites as well. These periods of record are critical for comparing data within and among gages and parameters – it is important to compare different gages or parameters over the same period of record, or else the risk of confounding comparisons of interest with temporal changes may be high. Of course, temporal changes are also of interest, and unfortunately most periods of record are shorter than we would like. Gage data are presented here to briefly summarize the temporal trends in flows, levels, temperature, and salinity that have occurred during the periods of record for gages in this system. Another purpose of this section is to familiarize the reader with data that are available from these gages. Some simple linkages between flows, levels, salinities, and temperatures are described here. However, application of this data to hydrodynamic modeling to address detailed quantitative links between these parameters is covered more thoroughly in later chapters and appendices.

Note that salinity values are reported as practical salinity units which are a dimensionless quantity. At times, practical salinity units are abbreviated as “psu”. If no units are given in reference to salinity, this is because salinity is a dimensionless ratio and has no units.

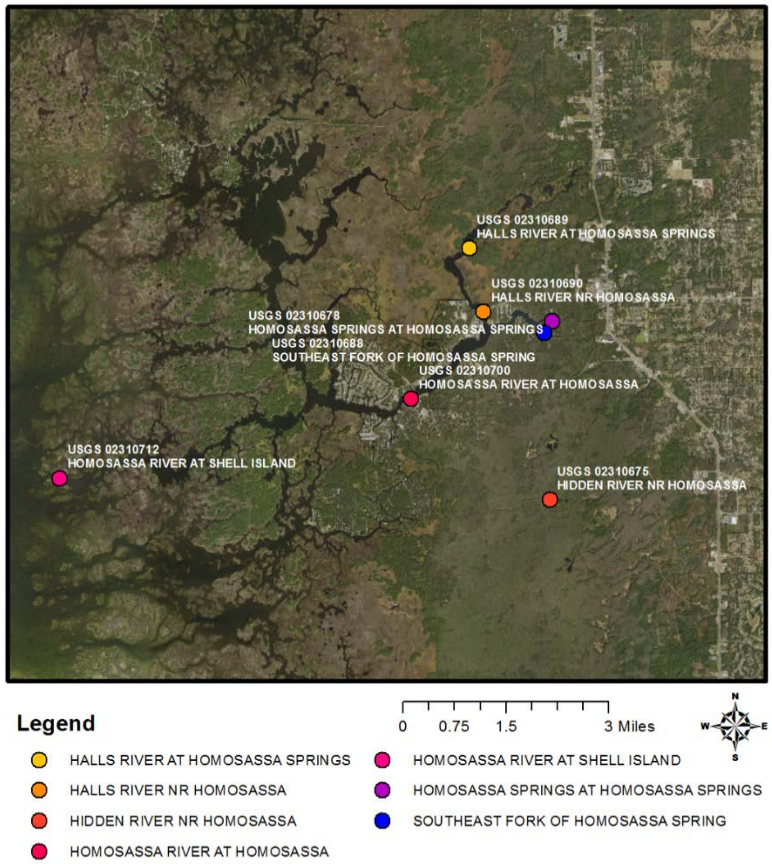


Figure 2-14. Current U.S. Geological Survey surface-water gages in the Homosassa River System.

Table 2-3. A) Periods of record for approved daily data as of March 27, 2018 for seven U.S. Geological Survey (USGS) gages in the Homosassa River System. Full records and additional data are available at the USGS National Water Information System website. B) Average daily data at seven USGS gages in the Homosassa River System. Shown are averages of daily maxima and minima for salinity, average of daily maximum temperature, and the average of daily average flow as reported by the USGS. Specific conductance at 25° C converted to salinity using equation by Lewis (1980) as reported in Schemel (2001).

A

Gage	Stage or Gage Height	Discharge	Specific Conductance	Temperature	Comments
USGS Homosassa Springs at Homosassa Springs, FL (Gage No. 02310678)	Mean: 1996-01-11 to 2010-09-29 Min/Max: 2010-10-01 to 2017-12-11	Mean: 1995-10-18 to 2017-12-11	Mean: 2016-06-08 to 2017-10-11 Min/Max: 2004-06-28 to 2017-10-11	Mean: 2016-06-08 to 2017-10-11 Min/Max: 2004-06-28 to 2017-10-11	Discharge from regression with well level and pool depth. Specific Conductance and Temperature at Bottom
USGS SE Fork Homosassa Spring at Homosassa Springs, FL (Gage No. 02310688)	Min/Max: 2010-10-01 to 2017-10-12 Tidal High-High and Low-Low: 2005-10-01 to 2010-09-30	Mean: 2000-10-01 to 2017-10-12 Tidally Filtered: 2012-10-03 to 2017-10-12	Mean: 2016-06-08 to 2017-10-12 Min/Max: 2006-05-03 to 2017-10-12	Mean: 2016-06-08 to 2017-10-12 Min/Max: 2006-05-03 to 2017-10-12	Specific Conductance and Temperature Near Bottom
USGS Hidden River near Homosassa, FL (Gage No. 02310675)	No Data	Mean: 2003-10-28 to 2017-12-04	No Data	No Data	Discharge from regression with well level
USGS Halls River at Homosassa Springs, FL (Gage No. 02310689)	Min/Max: 2012-03-09 to 2016-10-04	Tidally Filtered: 2012-03-10 to 2016-10-04	Mean: 2016-06-08 to 2017-10-15 Min/Max: 2012-03-09 to 2017-10-15	Mean: 2016-06-08 to 2017-10-15 Min/Max: 2012-03-08 to 2017-10-15	No location for Specific Conductance and Temperature
USGS Halls River near Homosassa, FL (Gage No. 02310690)	Min/Max: 2014-11-07 to 2017-12-12 Tidal High-High and Low-Low: 2000-10-28 to 2009-10-12	No Data	Mean: 2016-06-08 to 2017-10-15 Min/Max: 2006-06-21 to 2017-10-15	Mean: 2016-06-08 to 2017-10-15 Min/Max: 2006-06-21 to 2017-10-15	Specific Conductance and Temperature at Bottom
USGS Homosassa River at Homosassa, FL (Gage No. 02310700)	Min/Max: 1970-10-01 to 2017-12-13 Mean: 1997-07-01 to 1998-09-29 Tidal High-High and Low-Low: 1974-10-01 to 2010-09-30	Mean: 2004-05-18 to 2017-12-13 Tidally Filtered: 2004-05-19 to 2017-12-13	Min/Max: 2004-05-18 to 2017-10-17 Mean: 2016-06-08 to 2017-10-17	Mean: 2016-06-08 to 2017-10-17 Min/Max: 2004-05-18 to 2017-10-17	Specific Conductance and Temperature at Top and Bottom. Bottom POR shown here.
USGS Homosassa River at Shell Island near Homosassa, FL (Gage No. 02310712)	Min/Max: 1984-10-01 2018-02-21 Tidal High-High and Low-Low: 2006-09-15 2009-10-06	No Data	Mean: 2016-06-08 2017-10-17 Min/Max: 2006-09-19 2017-10-17	Mean: 2016-06-08 2017-10-17 Min/Max: 2006-09-15 2017-10-17	Specific Conductance and Temperature at Top, Middle, and Bottom. Bottom POR shown here.

B

Gage	Salinity (min)	Salinity (max)	Temp (max)	Flow (mean)
USGS Homosassa Springs at Homosassa Springs, FL (Gage No. 02310678)	1.7	2.5	23	88
USGS SE Fork Homosassa Spring at Homosassa Springs, FL (Gage No. 02310688)	0.4	1.2	24	60
USGS Halls River near Homosassa, FL (Gage No. 02310690)	2.0	4.0	26	No data
USGS Halls River at Homosassa Springs, FL (Gage No. 02310689)	3.6	4.8	26	39
USGS Hidden River near Homosassa, FL (Gage No. 02310675)	No data	No data	No data	8
USGS Homosassa River at Homosassa, FL (Gage No. 02310700)	2.7 (top)	6.4 (top)	26 (top)	201
USGS Homosassa River at Shell Island near Homosassa, FL (Gage No. 02310712)	15.4 (top)	22.9 (top)	25 (top)	No data

2.3.1 Homosassa Springs at Homosassa Springs, FL (Gage No. 02310678)

The USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678) is located at latitude 28°47'58" N, longitude 82°35'20" W, approximately 600 feet upstream of the bridge on nature trail within the Ellie Schiller Homosassa Springs Wildlife State Park, 0.8 miles west of town of Homosassa Springs, and 3.1 miles northeast of Homosassa (Figure 2-15) (USGS 2018).

Field measurements of flow at Homosassa Springs at Homosassa Springs, FL (Gage No. 02310678) date to 1930, and are very sparse before the mid-1960s, when measurements became more common, but it was not until 1996 that a large number of samples was taken to develop regressions for reporting flow (Knochenmus and Yobbi 2001, Figure 2-16).

The Homosassa Springs at Homosassa Springs, FL gage (No. 02310678) shows a tidal cycle in stage with an amplitude of about one foot between low-low and high-high tides (Figure 2-17). Salinity varies with tide (Figure 2-18). Gulf of Mexico tides, which drive tidal stage patterns at this station, are mixed diurnal and semi-diurnal with a higher-high tide, lower-high tide, higher-low tide, and lower-low tide in a 24 hour period. Tides are also affected lunar month patterns, with higher high and lower low tides (spring tides) during full and new moons. Other astronomical patterns cause longer term changes in tidal magnitude. Wind also affects tides, with onshore winds piling water up, and offshore winds lowering water levels.

Over the course of a typical year, flows peak in the mid-90s (cfs) in December and January, steadily decline to lows in the upper- 70s (cfs) in June and rise steadily through hurricane season back to their peak in the winter months (Figure 2-19). Daily flows average 88 cfs and vary between 70 and 106 for eighty percent of the time (Table 2-4). Reported discharges are calculated based on regression with the Weeki Wachee FLDN REPL Well near Weeki Wachee, FL (No. 283154082313701), which is located ~ 22 miles south of the gage site, in Hernando County.

Tides are highest in summer months (Figure 2-20). Discharge is driven by interactions between tide and groundwater levels. Increasing tides in summer months contribute to decreasing flows in May, June, and July, but by August, flows begin to rebound due to increasing aquifer levels, while tides remain high through September and October.

Water temperatures are relatively stable, varying less than 1°Celsius over the course of a day, with daily minima and maxima primarily ranging from 23 to 24° C over the course of a year (Figure 2-21). Salinity typically varies from lows just over 1.5 psu to highs around 2.5 psu, with higher salinities occurring with higher sea levels in the summer (Figure 2-22). Average daily salinity range is from 1.7 to 2.5.

Figure 2-15. Location of the USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678).

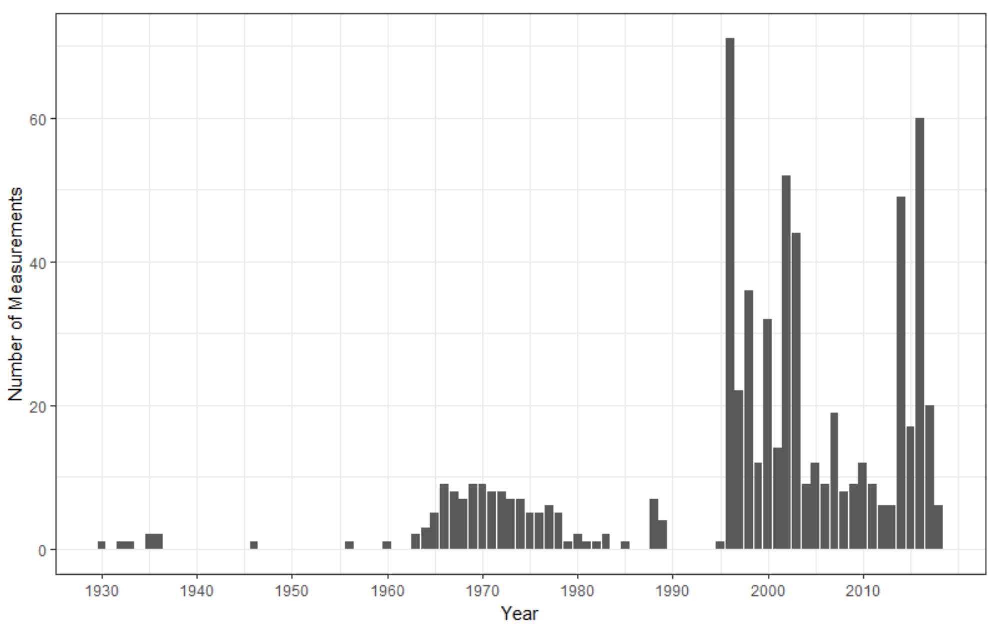


Figure 2-16. History of "field" measurements of flow at the USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678).

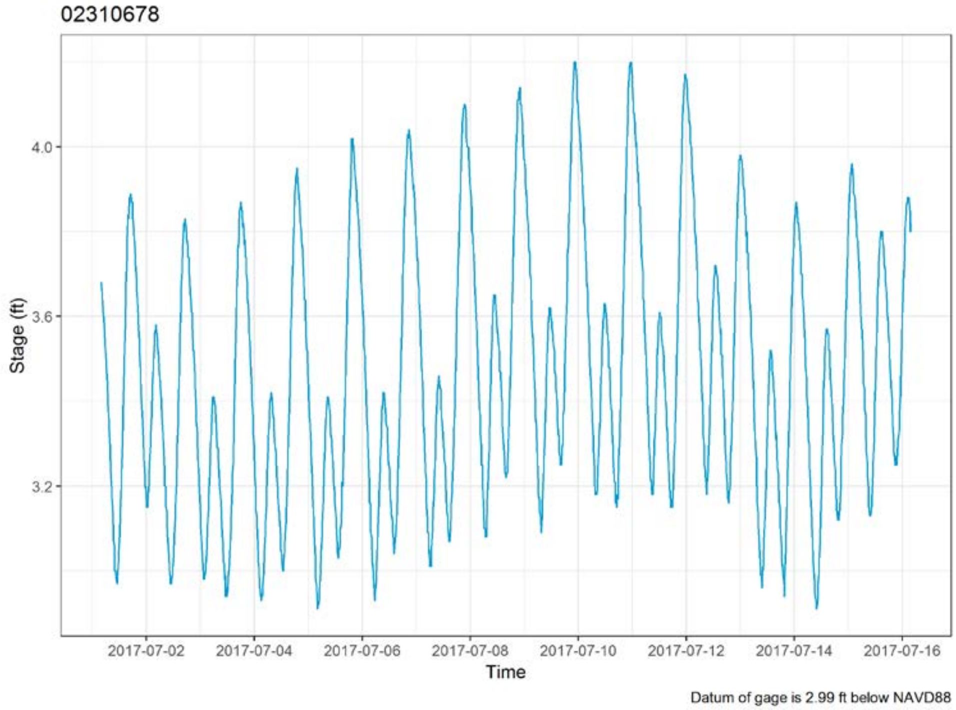


Figure 2-17. Stage height follows tidal cycle at the USGS Springs at Homosassa Springs gage (No. 02310678).

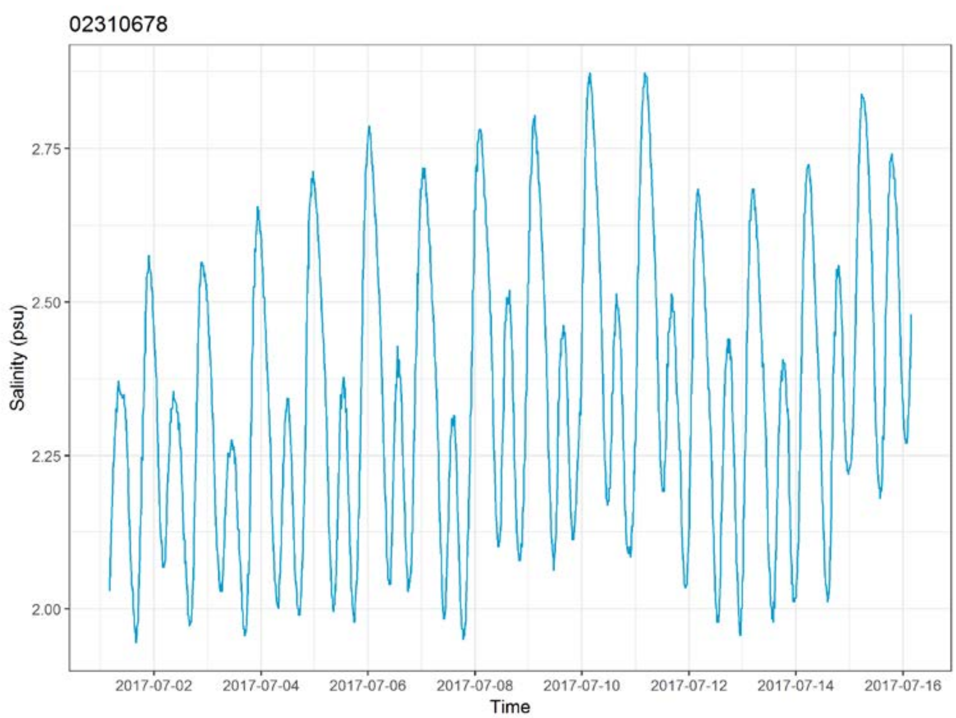


Figure 2-18. Salinity varies with tidal cycle at the USGS Homosassa Springs gage 02310678.

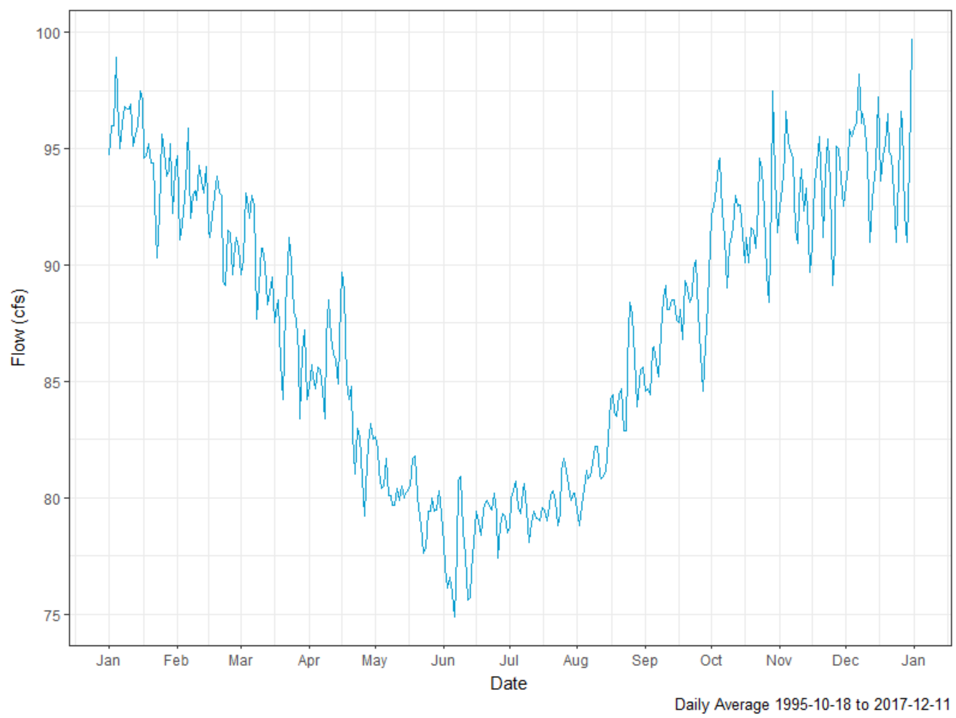


Figure 2-19. Day-of-Year average flows at the USGS Homosassa Springs at Homosassa Springs gage (No. 02310678).

Table 2-4. Summary statistics of flow (cfs) at the USGS Homosassa Springs at Homosassa Springs gage (No. 02310678), based on average daily "approved" values as reported in the USGS NWIS website (USGS 2018).

Start Date	End Date	Min	10^{th}	25^{th}	Mean	Median	75^{th}	90^{th}	Max
1995-10-18	2017-12-11	25	70	78	88	87	97	106	141

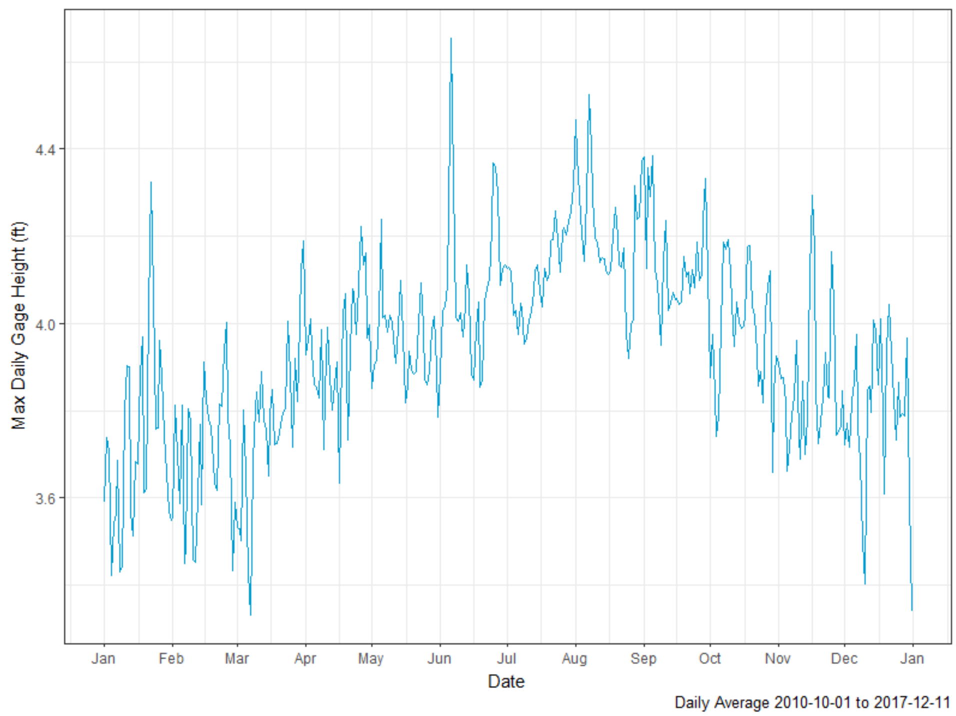


Figure 2-20. Daily high tides are higher in summer months at the USGS Homosassa Springs at Homosassa Springs gage (No. 02310678).

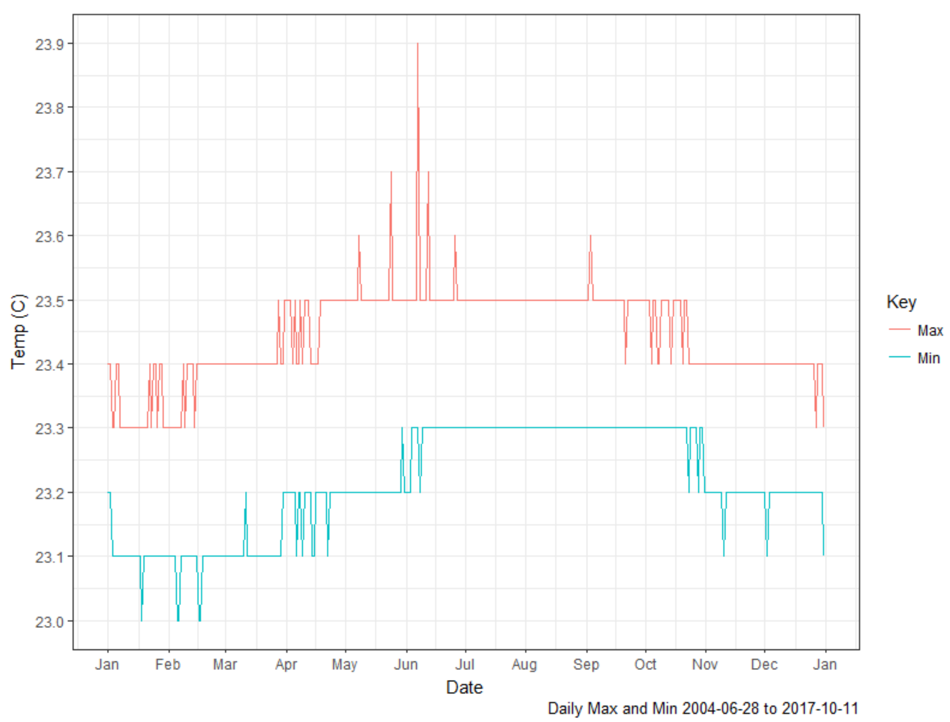


Figure 2-21. Day-of-Year minimum and maximum water temperatures recorded at the USGS Homosassa Springs at Homosassa Springs gage (No. 02310678).

Figure 2-22. Day-of-Year salinity minima and maxima at the USGS Homosassa Springs at Homosassa Springs gage (No. 02310678). Specific Conductance at 25°C converted to salinity using equation by Lewis (1980) as reported in Schemel (2001).

2.3.2 SE Fork Homosassa Spring at Homosassa Springs, FL (Gage No. 02310688).

The SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688) is located at latitude 28°47'50" N, longitude 82°35'24" W in Citrus County, FL, at the bridge on Fishbowl Drive, 0.6 miles west of town of Homosassa Springs, and 3.1 miles northeast of Homosassa (Figure 2-23) (USGS 2018).

The SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688) shows a tidal cycle in stage with an amplitude of about one foot between low-low and high-high tides (Figure 2-24). Salinity varies with tide but does not directly mirror stage because it hits a minimum of 0.5 psu while stage continues to drop (Figure 2-25).

Over the course of a typical year, flows (Tidally Filtered) peak in the low seventies (cfs) in August and September, decline to lows in the low fifties (cfs) in April and May, and rise steadily through hurricane season back to their peak (Figure 2-26). Daily flows average 60 cfs and vary between 50 and 70 for eighty percent of the time (Table 2-5). Reported flow is measured using index velocity and daily values are tidally filtered (non-filtered daily data is also available from NWIS, 15-minute data is not tidally filtered).

There is usually a one to two degree Celsius change in water temperature over the course of a day (Figure 2-27). Temperatures stay within 21.5 to 25.5 C. over the course of a year. Salinity drops to lows under 0.5 and reaches highs typically around 1 to 1.5, with higher salinities typical in May and June when flows are at their lowest (Figure 2-28).

Figure 2-23. Location of USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688).

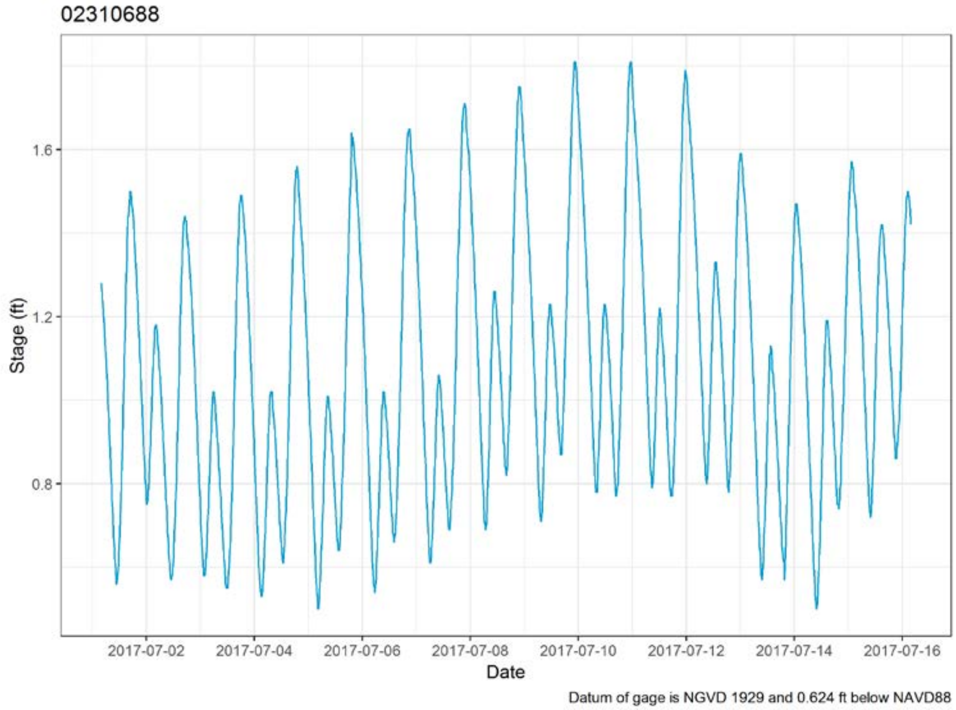


Figure 2-24. Stage height is driven by tides at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688).

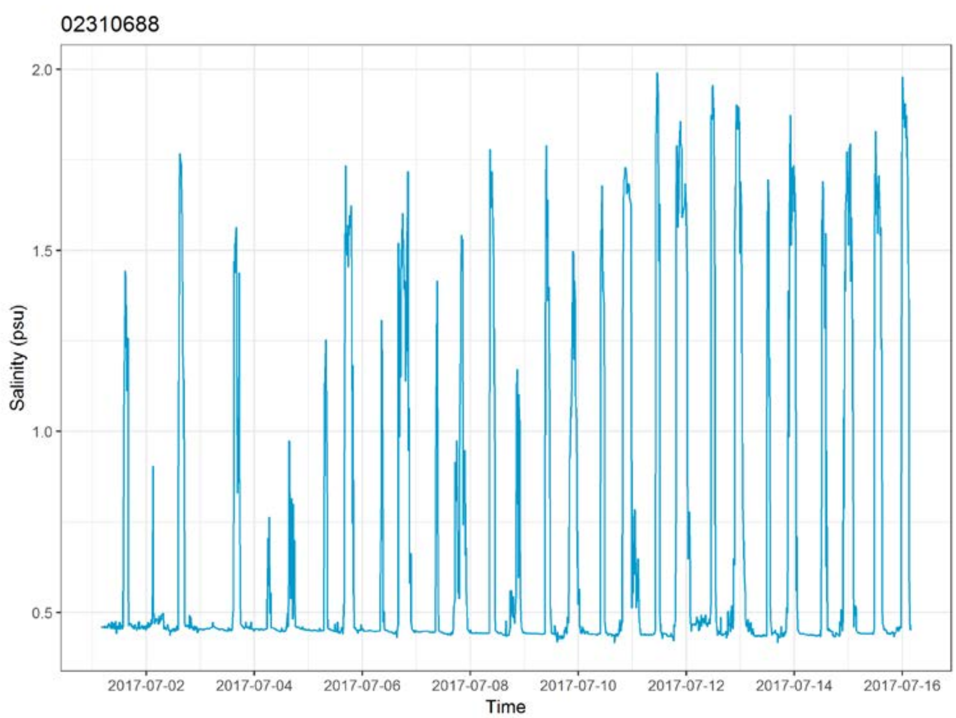


Figure 2-25. Salinity at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688) varies with tide.

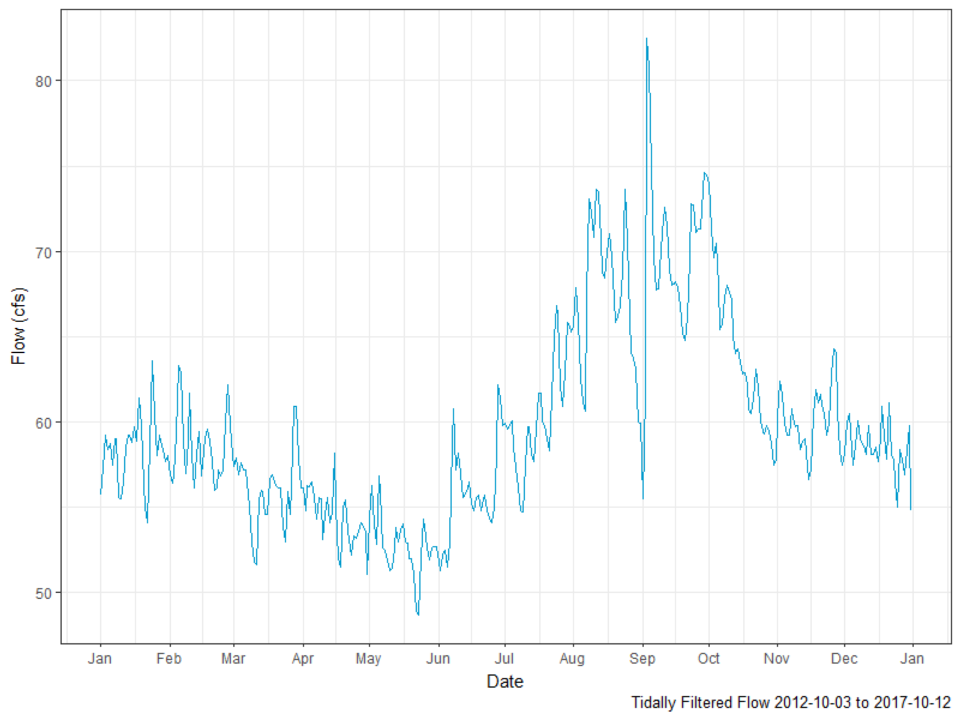


Figure 2-26. Day-of-Year average flows (tidally filtered) at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688).

Table 2-5. Summary statistics of tidally filtered flow (cfs) at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688), based on average daily values as reported by USGS NWIS.

Start Date	End Date	Min	10th	25th	Mean	Median	75th	90th	Max
2012-10-03	2017-10-12	28	50	54	60	59	64	70	133

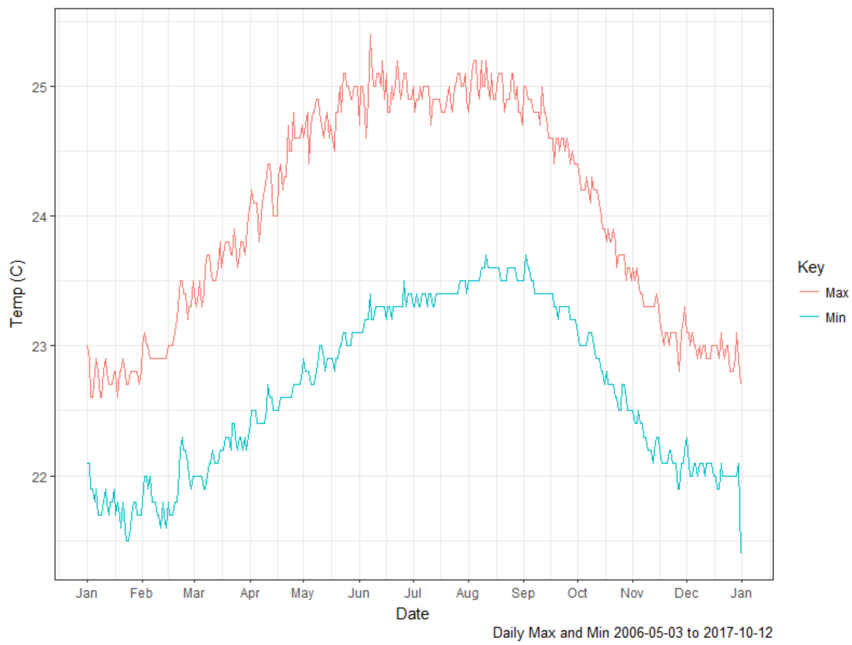


Figure 2-27. Day-of-Year minimum and maximum water temperatures recorded at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688).

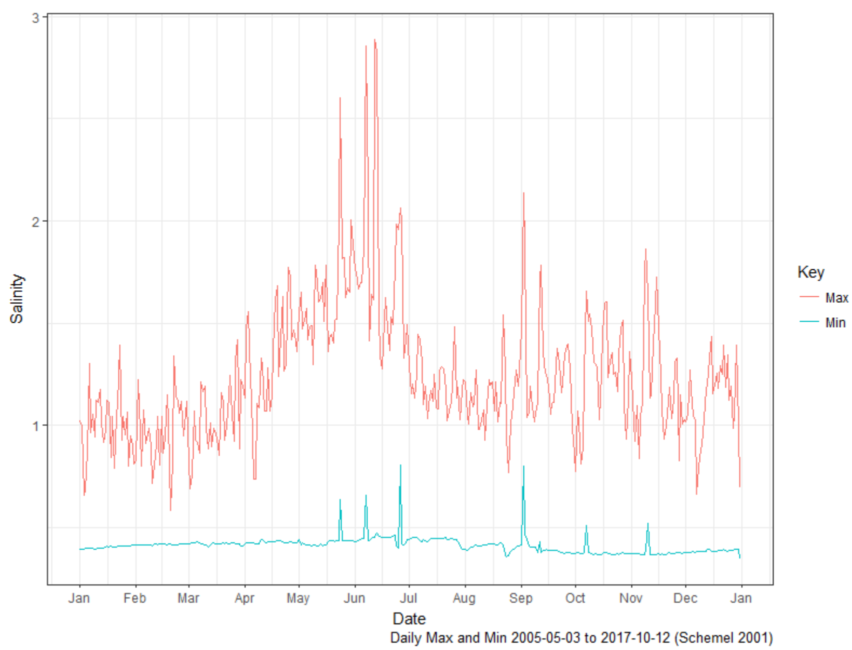


Figure 2-28. Day-of-Year salinity minima and maxima at the USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688). Specific Conductance at 25°C converted to salinity (psu) using equation by Lewis (1980) as reported in Schemel (2001).

2.3.3 Halls River at Homosassa Springs, FL (Gage No. 02310689)

The USGS Halls River at Homosassa Springs, FL (Gage No. 02310689) is located at latitude 28°48'47.2" N, longitude 82°36'20.3" W in Citrus County, FL, 27 feet from left bank, on a platform, 1.9 miles northwest of Homosassa Springs, and 1.28 miles upstream from mouth. (Figure 2-29). This gage was installed in 2012 after the all data for the 2012 minimum flows evaluation for the Homosassa River System had been collected.

The Halls River at Homosassa Springs, FL gage (No. 02310689) shows a tidal cycle in stage with an amplitude of about one foot between low-low and high-high tides (Figure 2-30). Over the course of a typical year, tidally-filtered flows range from around 30 to 60 cfs in August through March and decline to below 30 cfs in April through July (Figure 2-31). Daily flows average 39 cfs and vary between 4 and 73 for eighty percent of the time (Table 2-6). Reported flow is measured using an index velocity approach, and daily values are tidally filtered (15-minute data is not tidally filtered). Water temperatures fluctuate about 3°C over the course of a day, and around 10°C annually, with predictable highs around 30°C in the summer and lows reaching 15°C in the winter (Figure 2-32). Salinity, calculated from specific conductance, ranges between 3 and 5 (psu), and is lower in the summer months (Figure 2-33).

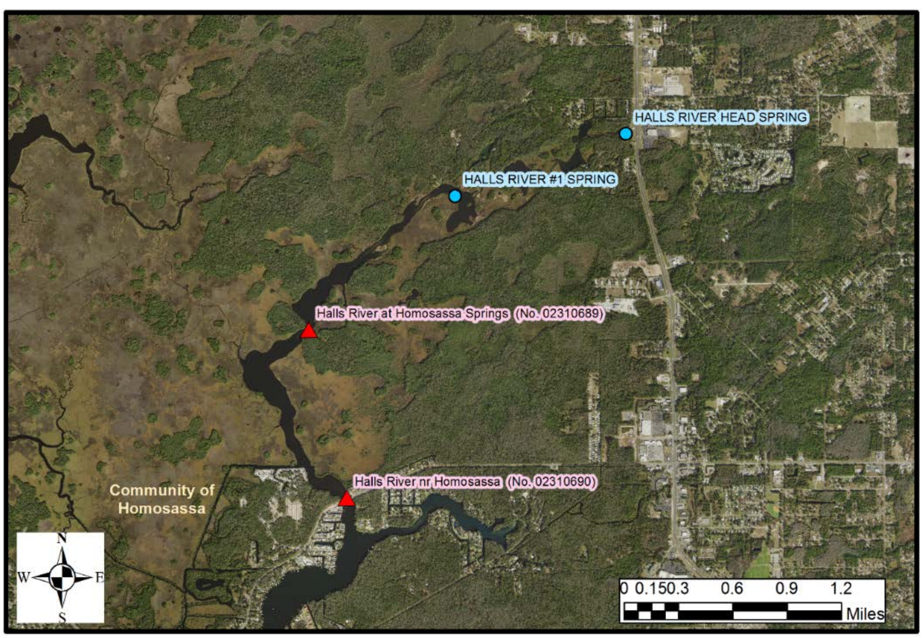


Figure 2-29. Location of the USGS Halls River at Homosassa Springs, FL gage (No. 02310689) and Halls River near Homosassa, FL gage (No. 02310690).

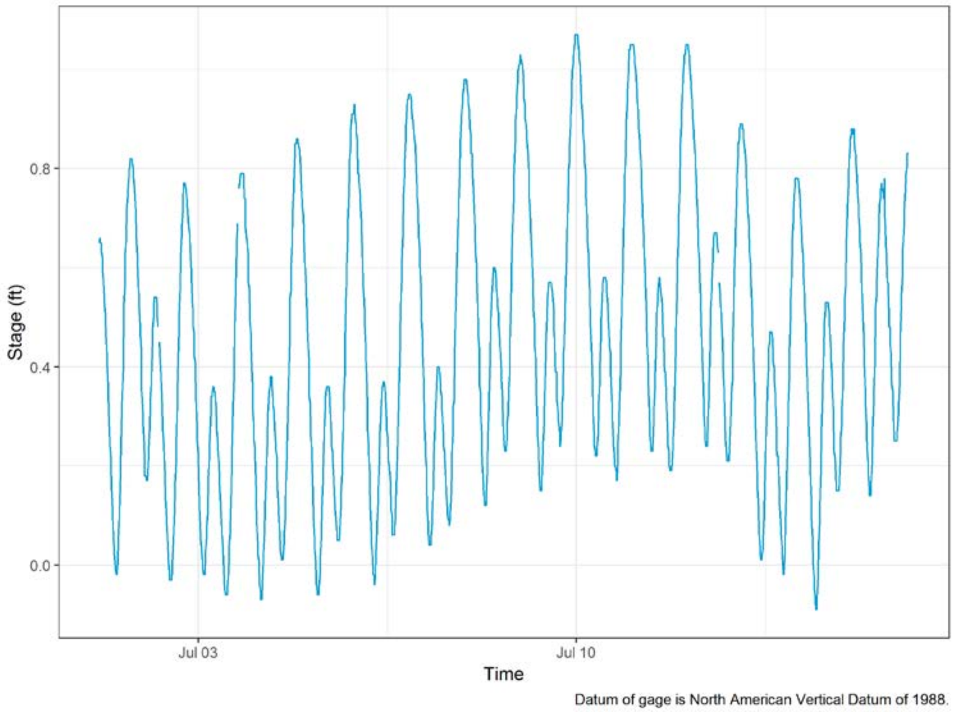


Figure 2-30. Stage height is driven by tide at the USGS Halls River at Homosassa Springs, FL gage (No. 02310689).

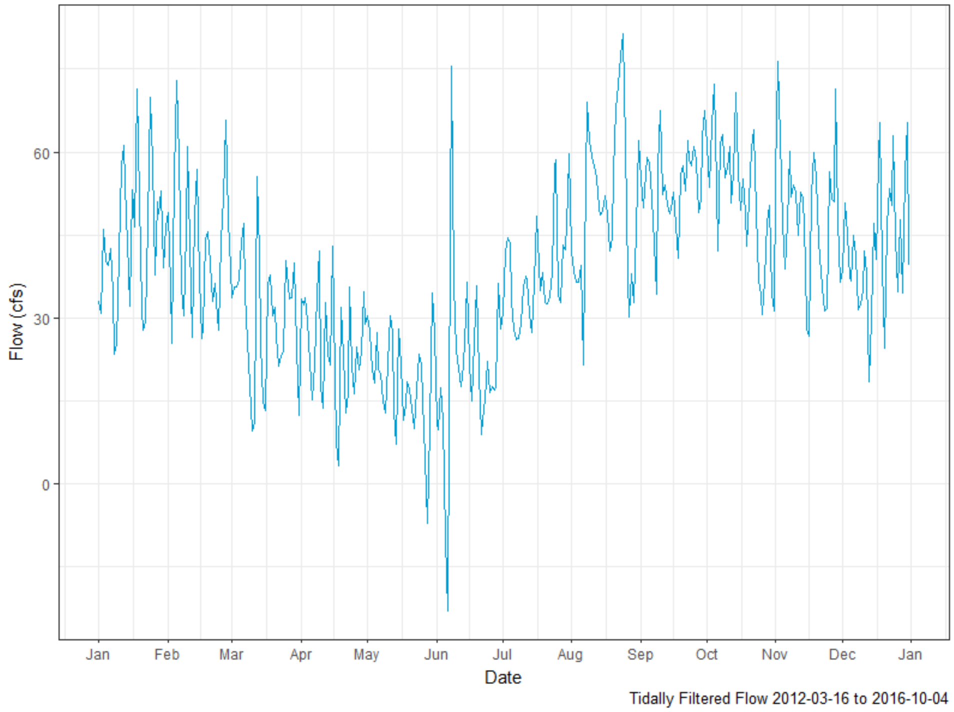


Figure 2-31. Day-of-Year average flows (tidally filtered) at the USGS Halls River at Homosassa Springs, FL gage (No. 02310689).

Table 2-6. Summary statistics of tidally filtered flow (cfs) at the USGS Halls River at Homosassa Springs, FL gage (No. 02310689), based on average daily values as reported in the USGS NWIS. The negative minimum value corresponds to storm surge associated with tropical storm Colin. Tidal filtering does not eliminate effects of tide on measured discharge but addresses mismatch between solar and lunar day lengths.

Start Date	End Date	Min	10^{th}	25^{th}	Mean	Median	75^{th}	90^{th}	Max
2012-03-16	2016-10-04	-184	4	19	39	37	55	73	252

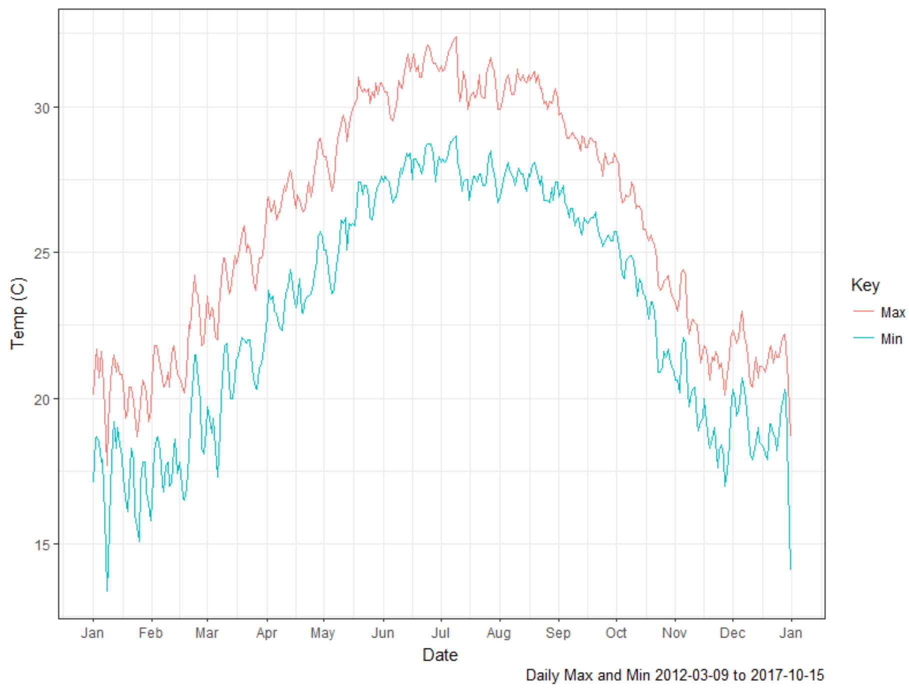


Figure 2-32. Day-of-Year minimum and maximum water temperatures recorded at the USGS Halls River at Homosassa Springs, FL gage (No. 02310689).

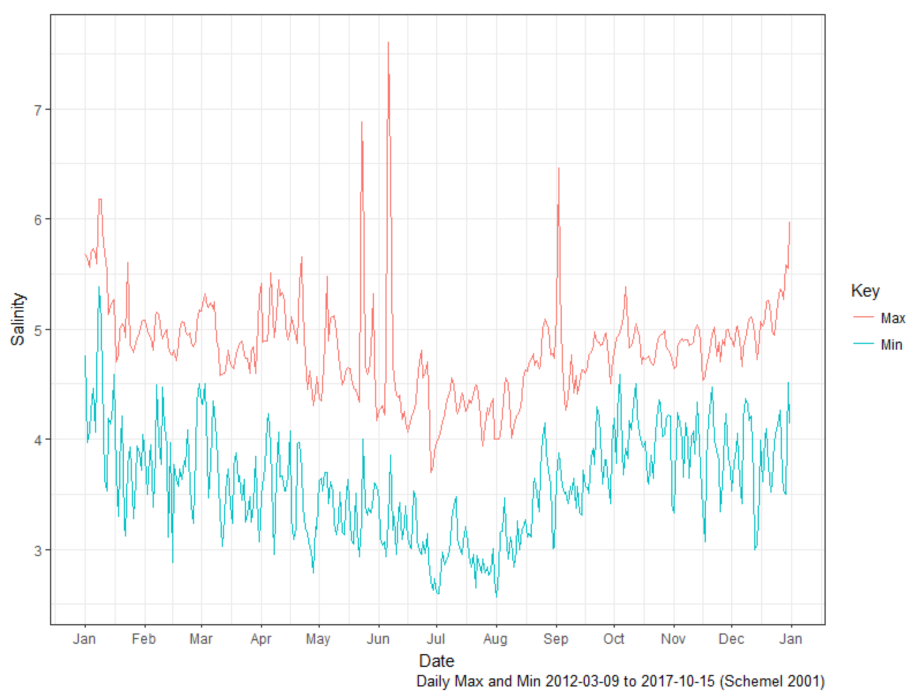


Figure 2-33. Day-of-Year salinity (psu) minima and maxima at the USGS Halls River at Homosassa Springs, FL gage (No. 02310689). Specific Conductance at 25°C converted to salinity using equation by Lewis (1980) as reported in Schemel (2001).

2.3.4 Halls River near Homosassa, FL gage (No. 02310690)

The Halls River near Homosassa, FL gage (No. 02310690) was installed in 2007 at latitude 28°48'04" N, longitude 82°36'10" W in Citrus County, FL at the bridge on Halls River Road, 1.9 miles west of the intersection of U.S. Highway 19 and Citrus County 490-A (Figure 2-29). This was the only gage on the Halls River during the original Homosassa River System minimum flows evaluation completed in 2012.

Water temperature, gage height, and specific conductance, but not discharge are recorded at the Halls River near Homosassa, FL gage (No. 02310690). This gage shows a tidal cycle in stage with an amplitude of about one foot between low-low and high-high tides (Figure 2-34). Water temperatures fluctuate about 3°C over the course of a day, and around 10° C annually, with predictable highs around 30° C in the summer and lows approaching 16° C in the winter (Figure 2-35). Salinity, measured as specific conductance, exhibits daily lows around 2 and highs can approach 8 (psu) (Figure 2-36).

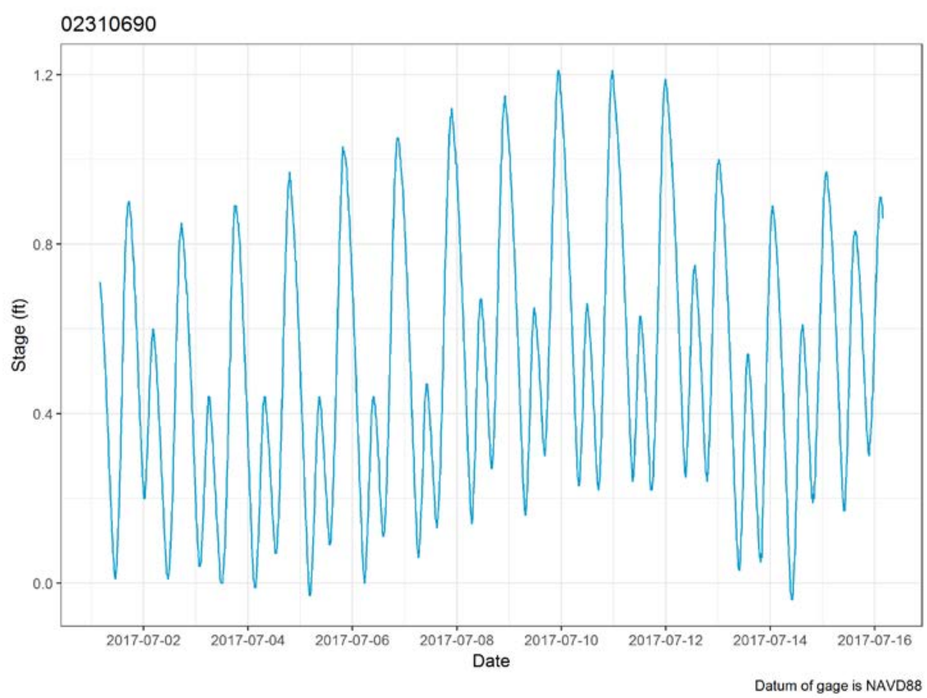


Figure 2-34. Stage height driven by tide at the USGS Halls River near Homosassa, FL gage (No. 02310690).

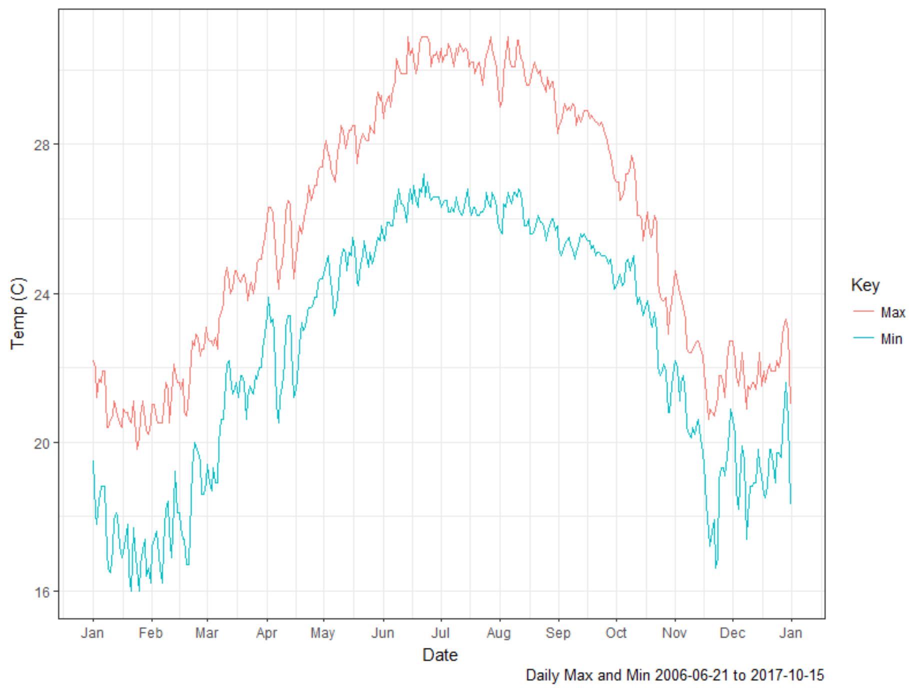


Figure 2-35. Day-of-Year minimum and maximum water temperatures recorded at the USGS Halls River near Homosassa, FL gage (No. 02310690).

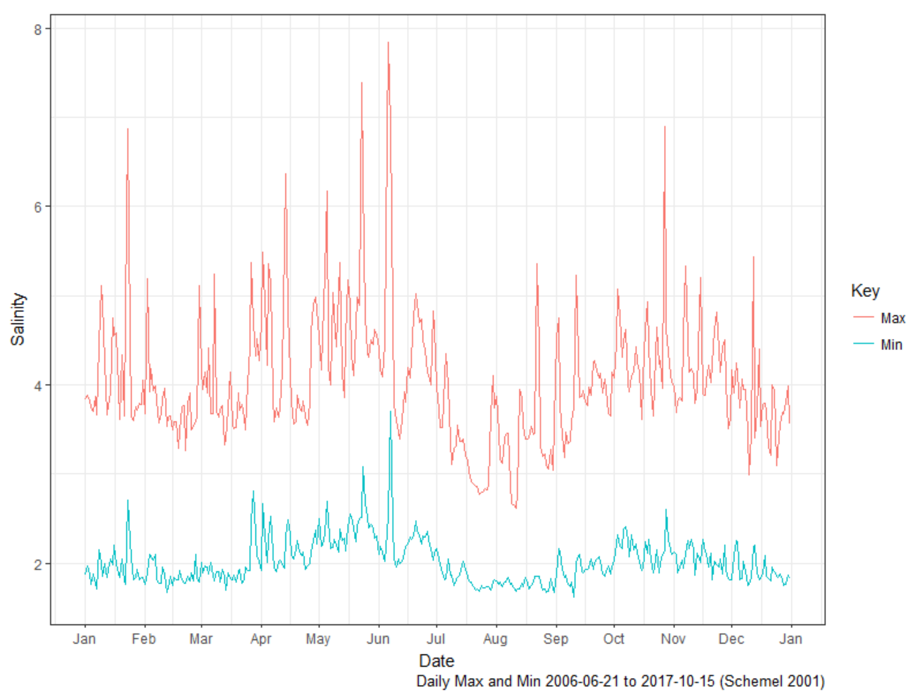


Figure 2-36. Day-of-Year salinity minima and maxima at the USGS Halls River near Homosassa, FL gage (No. 02310690). Specific Conductance at 25° C converted to salinity (psu) using equation by Lewis (1980) as reported in Schemel (2001).

2.3.5 Hidden River near Homosassa, FL gage (No. 02310675)

The Hidden River near Homosassa, FL gage (No. 02310675) is located at latitude 28°45'59" N, long 82°35'20" W in Citrus County, FL at on right bank, at Burnt Bridge Road, 2.0 mi southeast of Homosassa (Figure 2-14).

Daily discharge has been reported for the Hidden River Gage since October 2003. Over the course of a typical year, flows peak around 10 cfs in September, decline over the following seven months to lows around 5 cfs in May, and rise again in the summer months (Figure 2-37). Daily flows average 7.7 cfs and vary between 3.8 and 12.8 for eighty percent of the time (Table 2-7). Discharge is computed from relation between artesian pressure at USGS Homosassa Well 3 near Homosassa, FL (No. 284551082345301) located at latitude 28°45'50.5", longitude 82°34'53.6" in Citrus County on Burnt Bridge Road, 2.3 mi southeast of Homosassa, and 1.8 mi west of U.S. Highway 19, using maximum daily water level and discharge at measuring site. See USGS publication WRIR 01-4230 (Knochenmus and Yobbi 2001) for computation techniques.

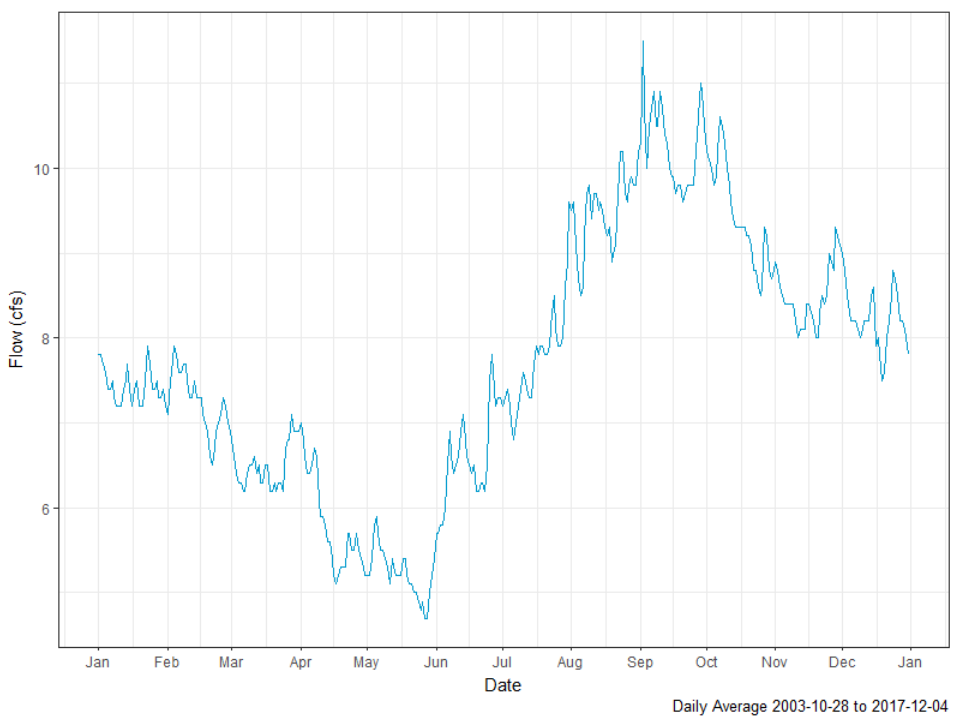


Figure 2-37. Day-of-Year average flows at the USGS Hidden River near Homosassa, FL gage (No. 02310675).

Table 2-7. Summary statistics of flow (cfs) at the USGS Hidden River near Homosassa, FL gage (No. 02310675), based on average daily values as reported by USGS NWIS.

Start Date	End Date	Min	10th	25th	Mean	Median	75th	90th	Max
2003-10-28	2017-12-04	1.32	3.84	5.04	7.72	6.78	9.74	12.8	35.4

2.3.6 Homosassa River at Homosassa, FL gage (No. 02310700)

The Homosassa River at Homosassa, FL gage (No. 02310700) is located at latitude 28°47'06" N, longitude 82°37'05" W in Citrus County, FL, on a private dock along the left bank of the river,, 0.3 miles northwest of Homosassa, and 5.3 miles upstream from river's mouth (Figure 2-14).

The Homosassa River gage shows a tidal cycle in stage with an amplitude of about one foot between low-low and high-high tides (Figure 2-38). Over the course of a typical year, flows average over 200 cfs from July through March, with values closer to 150 cfs typical in April through June (Figure 2-39). Day-of-year averages show large variation (plus or minus around 100 cfs) from one day to the next. Daily flows average 201 cfs and vary between 73 and 352 for eighty percent of the time (Table 2-8). Streamflow at this site is significantly affected by astronomical tides. The residual discharges are not total "freshwater" flow but are a combination of freshwater flow and water storage caused by higher or lower Gulf of Mexico mean water levels. The residual discharge is used to estimate mean discharge values. By convention, the U.S. Geological Survey has established ebb (seaward) flows as positive flow and flood (landward) flows as negative flows.

Water temperatures range from lows around 17° C in winter to highs around 31° C in summer. The difference between daily minimum and maximum temperatures is 2-3 C, while difference between top and bottom is mostly less than 0.2° C. (Figure 2-40). Salinity varies over the course of a day with tide, by time of year, and between top and bottom sensors (Figure 2-41). Salinity shows variation over daily tidal cycles, expressed as the difference between daily min and max, which is routinely a difference of 3 to 6 at both top and bottom sensors. Seasonally, maximum salinities range from around 5 to 9, while minimum salinities range from 2.5 to 3.5. The difference between top and bottom salinities is greater for daily maxima than minima, but both are usually less than one psu.

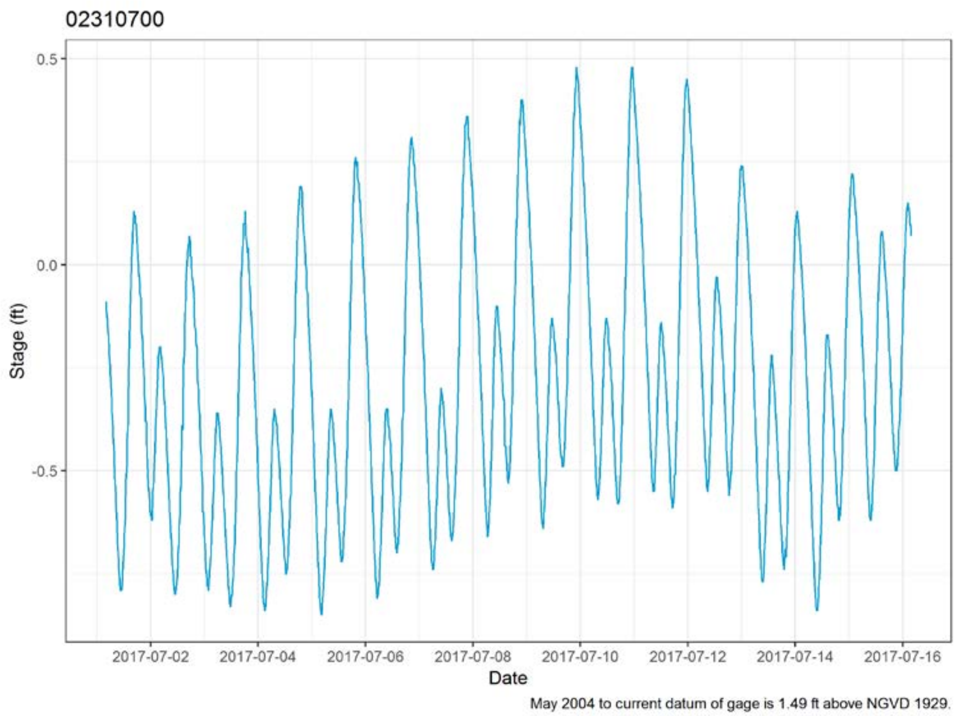


Figure 2-38. Typical tidal cycles in stage at the USGS Homosassa River at Homosassa, FL gage (No. 02310700).

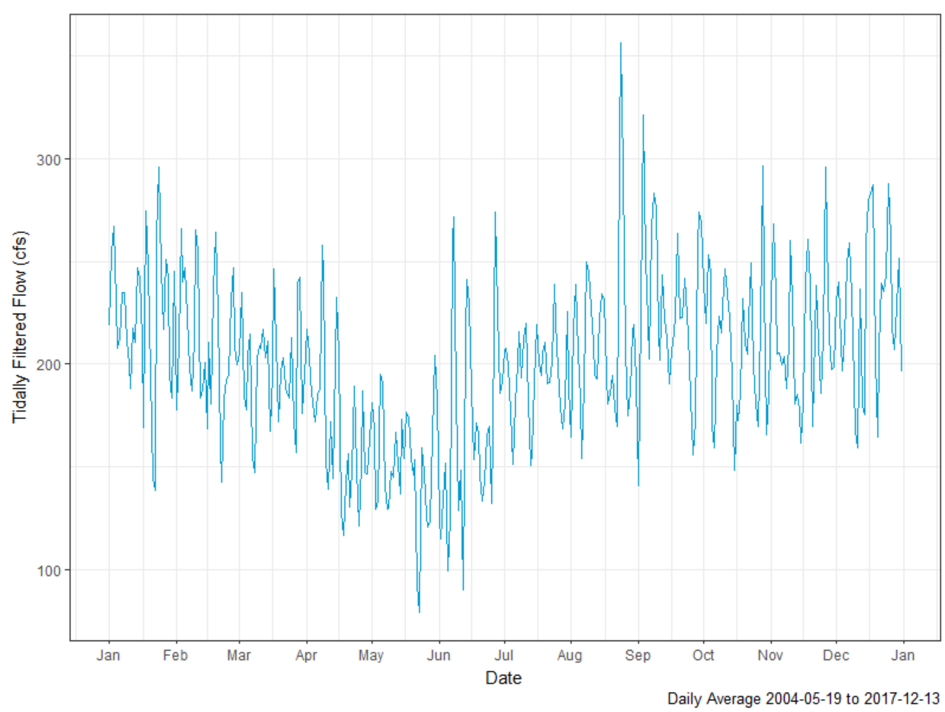


Figure 2-39. Day-of-Year average flows at the USGS Homosassa River at Homosassa, FL gage (No. 02310700).

Table 2-8. Summary statistics of flow (cfs) at the USGS Homosassa River at Homosassa, FL gage (No. 02310700), based on average daily values as reported by USGS NWIS.

Start Date	End Date	Min	10th	25th	Mean	Median	75th	90th	Max
2004-05-19	2017-12-13	-926	73	130	201	190	265	352	1490

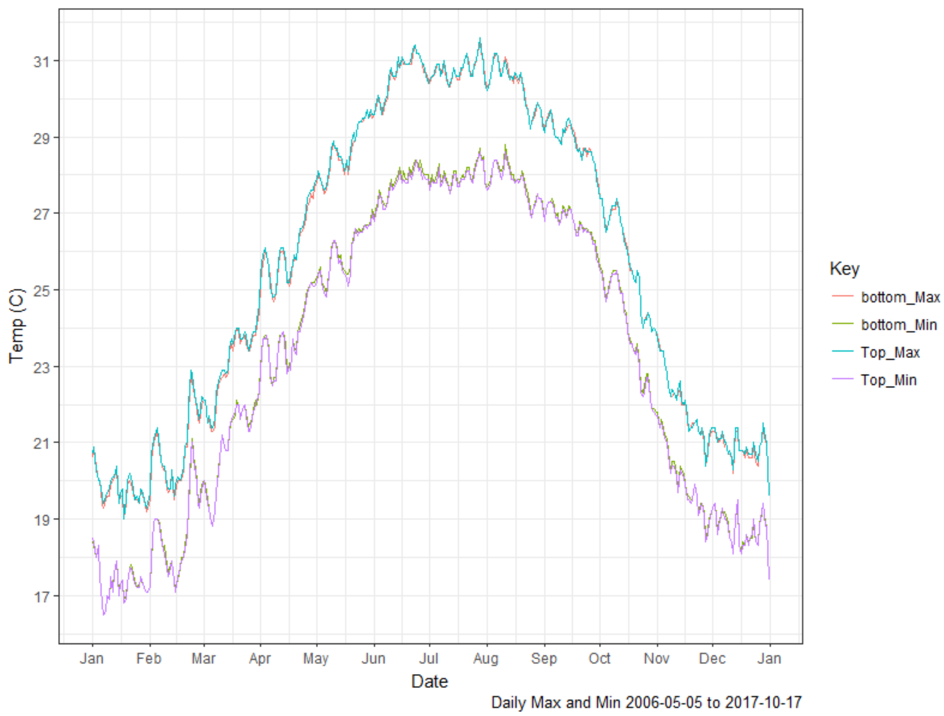


Figure 2-40. Day-of-Year minimum and maximum water temperatures recorded at top and bottom at the USGS Homosassa River at Homosassa, FL gage (No. 02310700). Sensors located 2.30 ft and 6.10 ft below gage datum.

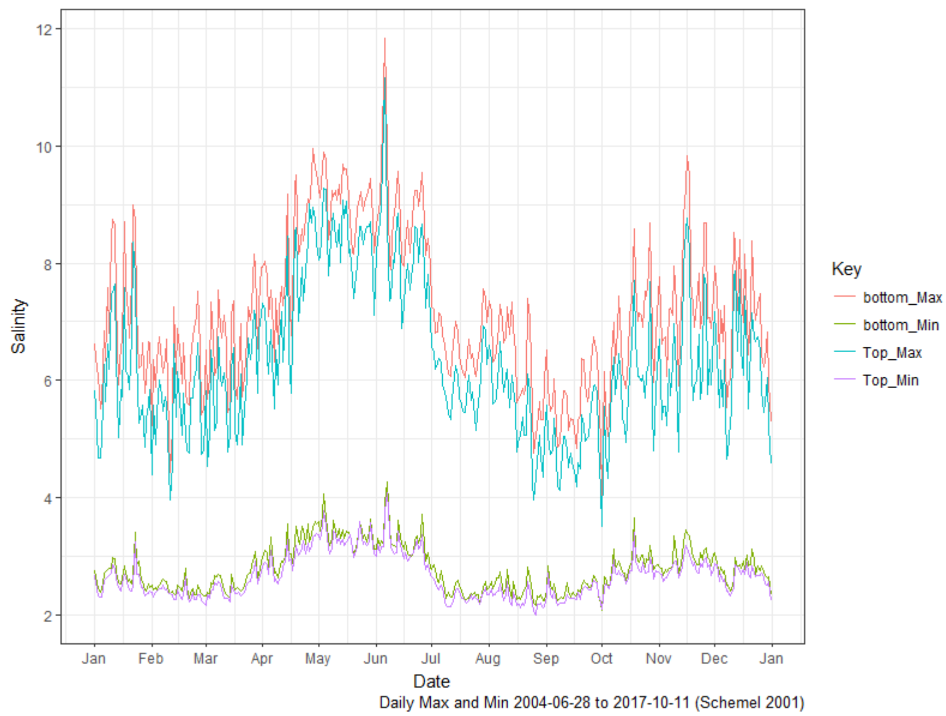


Figure 2-41. Day-of-Year salinity at top and bottom at the USGS Homosassa River at Homosassa, FL gage (No. 02310700). Specific Conductance at 25 C converted to salinity using equation by Lewis (1980) as reported in Schemel (2001). Sensors located 2.30 ft and 6.10 ft below gage datum.

2.3.7 Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712)

The Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712) is located at latitude 28°46'17" N, longitude 82°41'45" W in Citrus County, FL, on green channel marker #39 north of Shell Island and near the mouth of the Homosassa River (Figure 2-14).

Flow is not recorded at this gage. The Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712) shows a tidal cycle in stage with an amplitude of about 2.5 feet between low-low and high-high tides (Figure 2-42). Water temperatures range from lows around 15° C in winter to highs around 32° C in summer. The difference between daily minimum and maximum temperatures is around 2° C, while difference between top and bottom is mostly less than 0.1° C (Figure 2-43). Salinity varies over the course of a day with tide, by time of year, and between top and bottom sensors (Figure 2-44). Salinity shows the greatest variation over daily tidal cycles, expressed as the difference between daily min and max, which is routinely a difference of 3-6 at both top and bottom sensors. Seasonally, maximum salinities range from around 20 to 27, while minimum salinities range from 10 to 20. The difference between top and bottom salinities is greater for daily maxima than minima, but both are usually less than one psu.

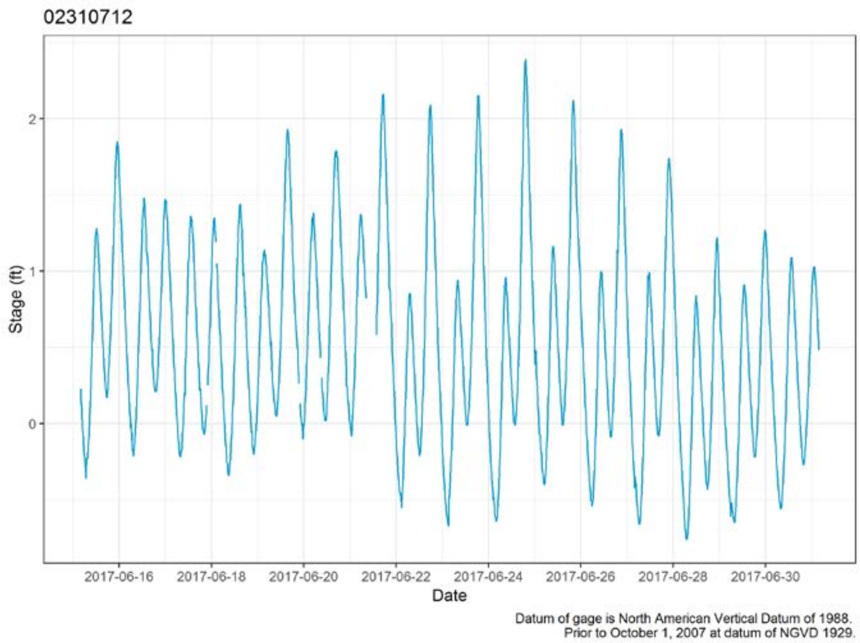


Figure 2-42. Typical tidal cycles in stage at the USGS Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712); June 22-25, 2017.

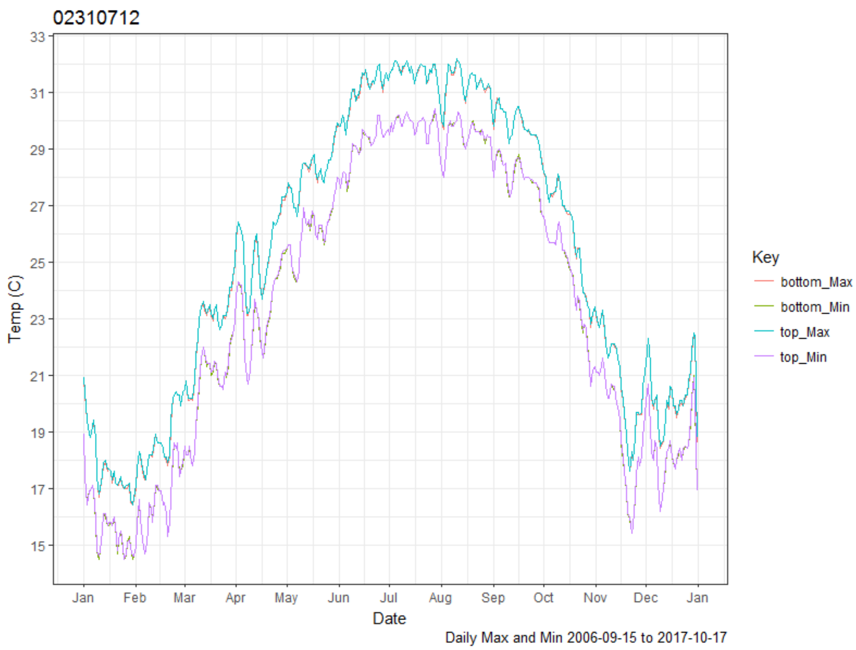


Figure 2-43. Day-of-Year top and bottom minimum and maximum water temperatures at the USGS Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712). Sensors are located near the surface and near the bottom of the river.

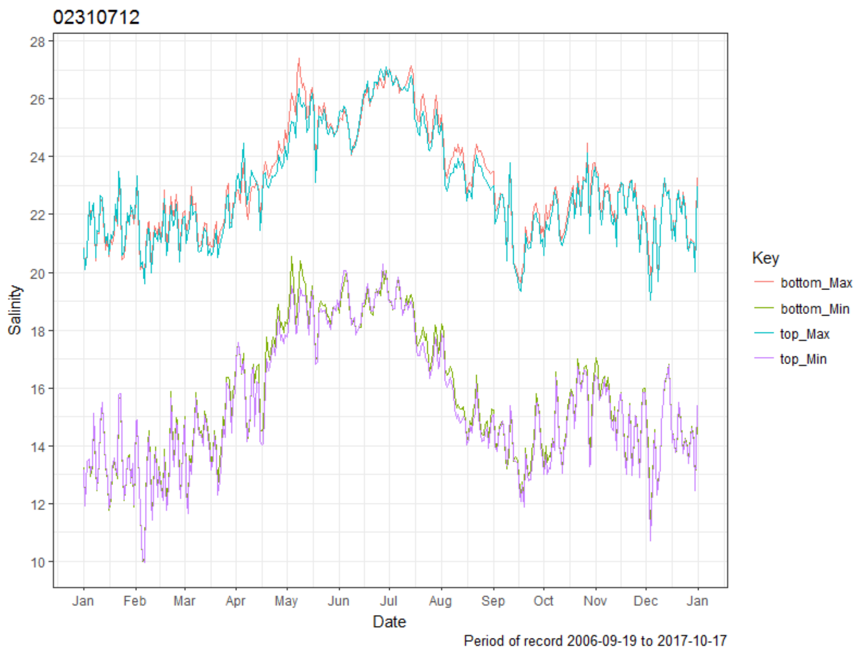


Figure 2-44. Day-of-Year top and bottom salinity at the USGS Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712). Specific Conductance at 25° C converted to salinity using equation by Lewis (1980) as reported in Schemel (2001). Sensors are located near the surface and near the bottom of the river.

2.4 Bottom Substrates

Sloan (1956) provides an early report on the bottom substrates of the Homosassa River from the headwaters area downstream to approximately river kilometer three. Based on sampling that was conducted in the early 1950s, substrates in the Homosassa Main Spring pool were characterized as fine yellow sand. At a site 0.2 miles downstream, Sloan (1956) noted an accumulation of organic detritus atop the sand substrate. Further downstream at a site just upstream of the confluence of the Halls and Homosassa Rivers, sediments included sand and fine black silt. Downstream substrates were characterized as mixtures of black silt, organic detritus and “shellbar”.

As part of a District-funded study of several Gulf coastal rivers, Frazer et al. (2001) report that mud is the most common bottom type in the Homosassa River, where it was the dominant substrate at 56.7 percent of the 100 sites sampled annually in 1998, 1999 and 2000 at 20 transects. Sand was the dominant substrate at 18.3 percent of the sampled sites and a mix of mud and sand was dominant at 15 percent of the sites. Although limestone outcrops are common along the entire river, rock was dominant at only three percent of the sampled sites and a mixture of rock and mud, sand or shell was dominant at about 6.3 percent of the sample sites. Similar results regarding substrate types were reported by Frazer et al. (2006) based on sampling of the river from 2003 through 2006 at the same sites surveyed between 1998 and 2001.

Arcadis (2016 [Appendix 3]) collected sediment data in October 2015. They found that silt generally increases downstream, transitioning from fine sand to silty sand around Rkm 10. The authors of this report claim that there is an overall increase in fines in the downstream section. This is supported by regression analysis run by District staff, who found that there is a positive ($R^2 = 0.67$), significant ($p < 0.005$) trend between percent fines and transect location (with fines increasing downstream) (Figure 2-45). Arcadis (2016) also claims that percent fines and percent organic material “appear to trend together”. District staff confirmed that there is a positive ($R^2 = 0.87$), significant ($p < 0.001$) linear relationship between percent fines and percent organic matter. However, Arcadis (2016) also claim that “a significant longitudinal trend for organic content is not apparent.” There are no statistical analyses given to support this statement. In contrast to this unsupported statement, District staff found a moderate ($R^2 = 0.39$), significant ($p < 0.05$) linear relationship between percent organic material and transect location (with organics increasing downstream). This makes sense because if fines are correlated with location, and fines and organics are correlated, then we expect to see organics also correlated with location.

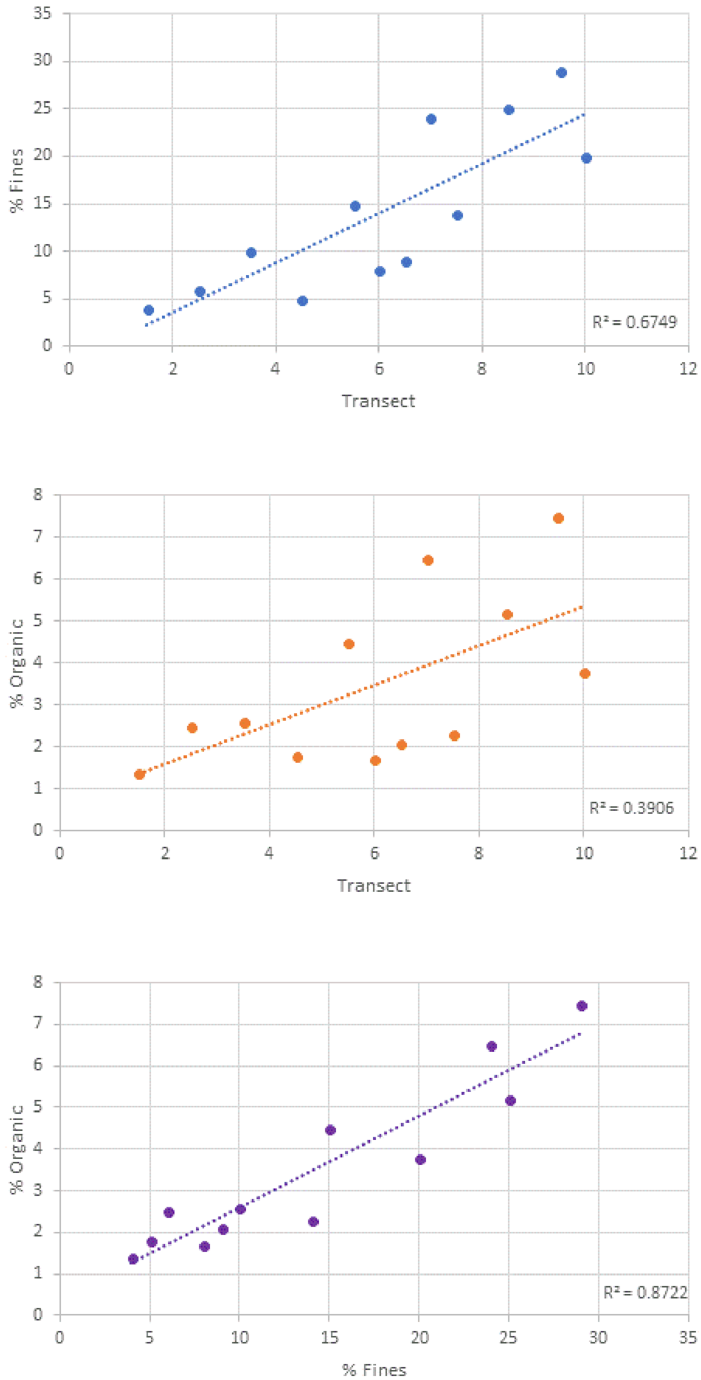


Figure 2-45. Sediment trends from October 2015 sampling in the Homosassa River (Arcadis 2016).

2.5 Flow Records

2.5.1 Differences in Flow Records

There are many flow records that were used in the development of this minimum flows evaluation. A general flow record was developed based on the reported discharges at gaging stations summarized in section 2.3. This general flow record was then modified for use in water quality analyses described in Chapter 3 and for hydrodynamic modeling described in Chapter 6 and Chen (2019a [Appendix 6]). These flow records differ in their periods of record, data frequency, treatment of missing dates, scaling of impacts, and inclusion of additional inputs at tributaries and adjustments for net flow (Table 2-9).

The general flow record, more fully described below, has a period of record limited to the gaged flows at USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678) and USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688). Daily flows are used as reported and approved by the USGS. On dates when data is missing, no flows are reported, and these are left blank in the flow record. No additional flows are added nor are adjustments made for tidal water movement past this gage.

The water quality flow record is constructed in the same manner as the general record except that it predicts flows prior to the gage period of record and fills in missing data by regression with the Weeki Wachee well (see Chapter 3.5.1). This in-filling was done to make use of water quality data for dates when gaged flow data was missing.

The LAMFE model flow record is constructed using 15-minute data. Like the general record, missing data was left missing. Impacts were kept at a constant value of 1.9% based on the most recent NDM estimate. In addition, the LAMFE model needs to more accurately predict net spring flows at the main springs and tributaries. Thus, additional flows were added as described in Chapter 3 of the hydrodynamic modeling report Chen (2019a [Appendix 6]). These additional flows were added in order to accurately model the locations and quantities of spring water additions to the system.

Table 2-9. Differences in flow records

Record	Period of Record	Data Frequency	Missing Dates	Impacts	Inputs
General	2000-10-01 to 2018-10-01	Daily	Left missing	Gradually increased	Gaged only
Water Quality	1975-01-01 to 2018-10-01	Daily	Estimated	Gradually increased	Gaged only
LAMFE	2007-10-09 to 2018-03-12	15-minute	Left missing	Constant	Adjusted for tides and tributaries

2.5.2 The General Flow Record

Gage Flow data from USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678) and USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688) were downloaded from USGS NWIS using the data Retrieval R package (De Cicco et al. 2018). These gages both report discharge (param code 00060) as a mean daily value. Data were filtered to include only approved values. Gages have differing periods of record and dates with missing data (Table 2-10). A combined record consists of the sum of flows for all dates when both gages report approved data (Figure 2-46). Missing dates were not in-filled with data from other sources or interpolation between dates.

Table 2-10. Periods of record and observations for gages.

Gage	Period of Record	Observations	Total Days	Missing days
USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678)	1995-10-18 to 2018-10-01	7996	8385	389
USGS SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688)	2000-10-01 to 2018-10-15	6103	6589	486
Combined	2000-10-01 to 2018-10-01	5850	6575	725

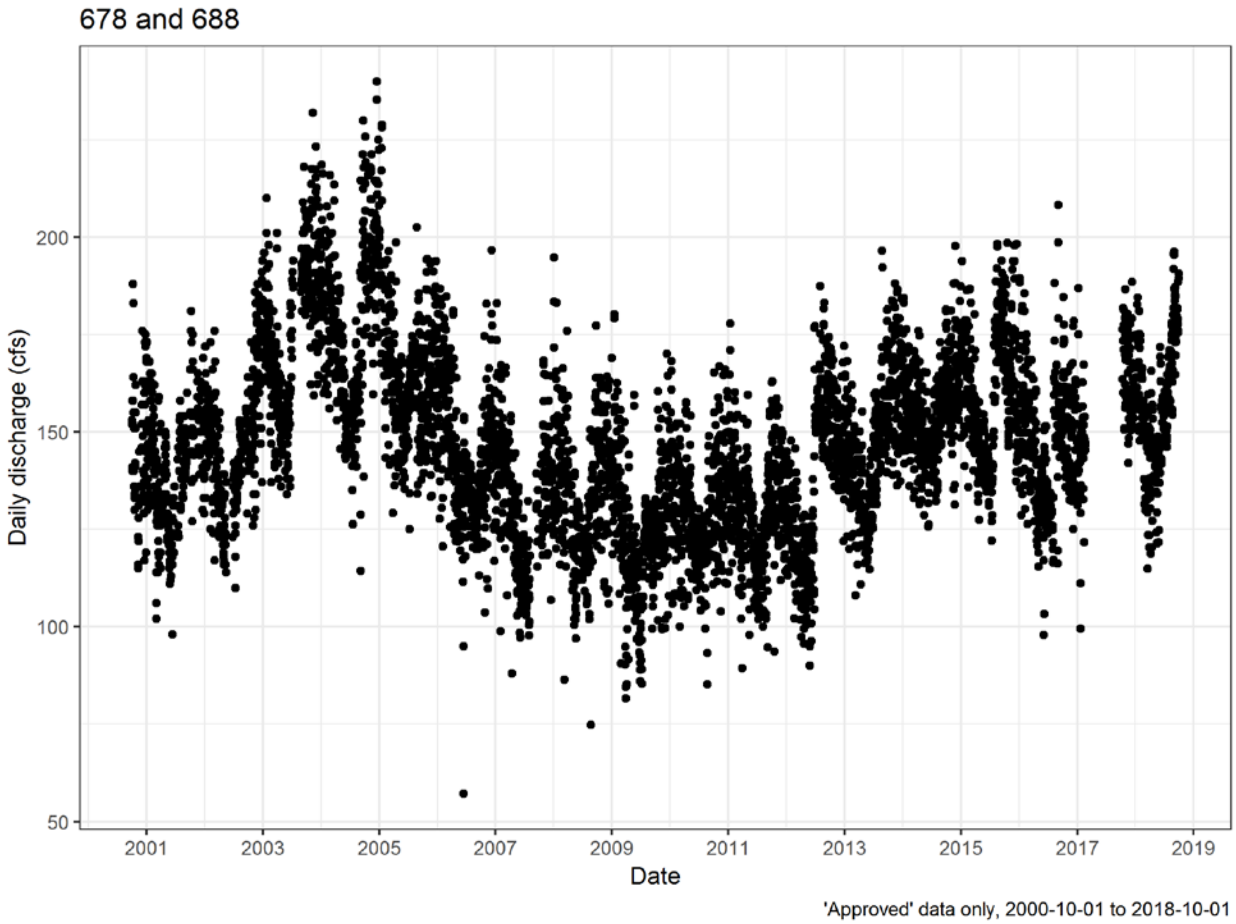


Figure 2-46. Combined flows from Homosassa springs gages 02310678 and 02310688.

CHAPTER 3 - WATER QUALITY CHARACTERISTICS AND RELATIONSHIPS WITH FLOW

3.1 Introduction

Water quality is one of 10 “Environmental Values” defined in the State Water Resource Implementation Rule (Chapter 62-40 F.A.C.) to be considered when establishing minimum flows. The water quality constituents of the Homosassa River and estuary discussed here are reviewed in the context of the original 2012 MFL report (Leeper et al. 2012) but are not intended to duplicate that work. This chapter presents an overview of the status and trends for water quality parameters of concern, specifically those parameters related to existing state standards. In addition, this chapter summarizes the results of work completed by Janicki Environmental, Inc. and WSP, Inc. under a District Task Work Assignment (TWA 18TW0001116) (Janicki Environmental, Inc. and WSP, Inc. 2018 [Appendix 7]). The purpose of Janicki Environmental, Inc. and WSP, Inc. (2018) was to conduct an exploratory evaluation of water quality and flow relationships for the Homosassa River. Specific tasks associated with Janicki Environmental, Inc. and WSP, Inc. (2018) consisted of data gathering, exploratory data analysis, stochastic predictive modeling, and synthesizing information to support the revaluation of minimum flows for the Homosassa River. For those parameters that have adopted water quality standards, the standards are included in many of the plots and analyses in this chapter and in Appendix 8. The inclusion of adopted water quality standards is for informational purposes only and are not intended to be a determination of impairment.

3.1.1 Water Quality Classification

Under Rule 62-302.200, F.A.C., Florida’s surface water quality standards consist of four components: 1) the designated use or classification of each water body, 2) the surface water quality criteria (numeric and narrative) for each water body, which are established to protect its designated use, 3) the anti-degradation policy, and 4) moderating provisions, such as mixing zones. Each surface water body in Florida is classified according to its present and future most beneficial use, referred to as its designated use, with class-specific water quality criteria for select physical and chemical parameters, which are established to protect the water body’s designated use (Chapter 62-302, F.A.C.). Most coastal waters of Citrus County, including the Homosassa River upstream to about river kilometer 8.4, are classified as Class II waters with a designated use of shellfish propagation or harvesting (Rule 62-302.400(16)(b), F.A.C.). The upper portion of the Homosassa River, Halls River, Hidden River and the springs associated with the Homosassa River system are all designated as Class III waters with designated uses of recreation and the propagation and maintenance of a healthy, well-balanced population of fish and wildlife (Rule 62-302.400, F.A.C.). All water bodies in the Homosassa River System are classified as Outstanding Florida Waters, a designation associated with Florida’s anti-degradation policy (Rule 62-302.700, F.A.C.). In addition, the Homosassa River is also designated a Southwest Florida Water Management District Surface Water Improvement and Management (SWIM) Priority Waterbody and as such, has a comprehensive SWIM Plan, approved by the Springs Coast Steering Committee and the District’s Governing Board in August 2017.

3.1.2 Impaired Waters Rule

Section 303(d) of the Federal Clean Water Act requires each state to identify and list "impaired" waters where applicable water quality criteria are not being met. To meet the reporting requirements of the Federal Clean Water Act, the State of Florida publishes the Integrated Water Quality Assessment for Florida. Assessment is made based on specific segments each assigned a specific Waterbody Identification (WBID). There are several WBIDs that make up the Homosassa River (Figure 3-1). These WBIDs have corresponding limits for select water quality parameters identified as numeric nutrient criteria (NNC) and total maximum daily loads (TMDLs) (Table 3-1).

The most recent assessment report to date was published in June 2018 (Florida Department of Environmental Protection 2018). As of August 21, 2018, none of the Homosassa WBID's were on the Statewide Comprehensive Verified List of Impaired Waters. However, this is partly because once a TMDL has been adopted, the WBID for which the TMDL applies is then removed or "delisted" from the verified list of impaired waters. Delisting a WBID does not imply that the WBID is no longer impaired, but it is removed from the verified list. The original minimum flow report (Leeper et al. 2012) for the Homosassa River system cited several WBIDs as being impaired for nutrients (algal mats) and mercury (in fish tissue), including Direct Runoff to Gulf (WBID 1348), Gulf of Mexico, Citrus County (WBID 8041A), Homosassa River (brackish portions) (WBID 1345), Game Creek (WBID 1345B), Homosassa River (shellfish portion) (WBID 1345F) and Otter Creek (WBID 1348C) as being listed as impaired. These WBIDs previously verified for mercury (fish tissue) have been removed from the verified impaired waters list ("delisted") because they have either been reclassified or now have a DEP-adopted mercury Total Maximum Daily Load (TMDL). Similarly, Bluebird Springs (WBID 1348A), Hidden River Springs (1348E) and Homosassa-Trotter-Pumphouse Springs Group (WBID 1345G) have been "delisted" from the impaired waters list for Nutrients (algal mats) because they have a DEP-adopted nitrate TMDL (Bridger et al. 2014).

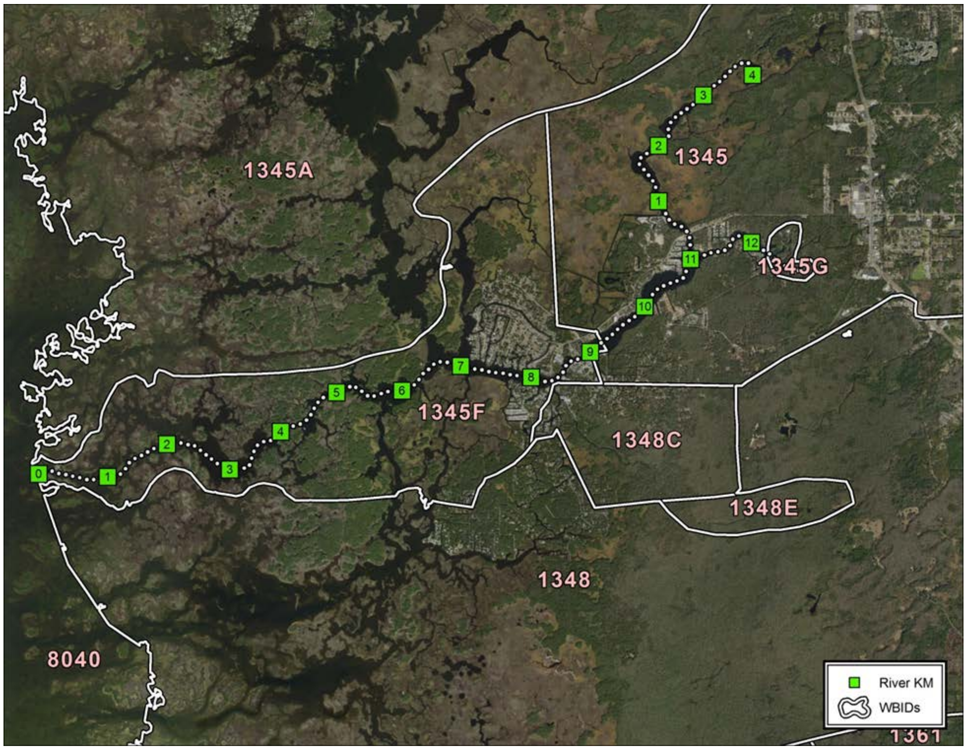


Figure 3-1. Map of Homosassa River with DEP Waterbody ID (WBID) boundaries and the river kilometers (Rkm) system used for the development of this minimum flows evaluation.

Table 3-1. Site-specific numeric nutrient criteria (NNC) and Total Maximum Daily Loads (TMDL) associated with Water Body IDs (WBID) for the Homosassa River System.

	NNC			**TMDL**
	Total Nitrogen	Total Phosphorus	Chlorophyll a	Nitrate
Homosassa River Estuary (WBID 1345F)	0.51 mg/L	0.028 mg/L	7.7 µg/L	
Bluebird Springs (WBID 1348A)				0.23 mg/L
Hidden River Springs (WBID 1348E)				0.23 mg/L
Homosassa-Trotter-Pumphouse (WBID 1345G)				0.23 mg/L

3.1.3 Numeric Nutrient Criteria

Given the global extent of water quality degradation associated with nutrient enrichment, eutrophication poses a serious threat to potable drinking water sources, fisheries, and recreational water bodies (Chislock et al. 2013). Nutrient enrichment continues to be a major issue in Florida waters. In 2011, the state of Florida adopted quantitative nutrient water quality standards to facilitate the assessment of designated use attainment for its waters and to provide a better means to protect state waters from the adverse effects of nutrient over enrichment (Florida Department of Environmental Protection 2009). To that end, the DEP developed numeric criteria for causal variables (phosphorus and nitrogen) and/or response variables (chlorophyll), recognizing the hydrologic variability (waterbody type) and spatial variability (location within Florida) of the nutrient levels of the state's waters, and the variability in ecosystem response to nutrient concentrations. Because nutrient effects on aquatic ecosystems are moderated by many natural factors (e.g., light penetration, hydraulic residence time, presence of herbivore grazers and other food web interactions, and habitat considerations), the DEP recognized that determining the appropriate protective nutrient regime is largely a site-specific undertaking, requiring information about ecologically relevant responses (Florida Department of Environmental Protection 2013).

In July 2013, the DEP published site-specific numeric nutrient criteria (NNC) for the Springs Coast including the estuarine segment of the Homosassa River. The estuarine segment extends from the mouth of the river upstream to the point at which the river becomes predominantly fresh and is that part of the river contained within WBID 1345F; the Homosassa River Estuary. This WBID 1345F has established site-specific NNC for total phosphorous (TP), total nitrogen (TN), and chlorophyll concentrations (Table 3-1). To date, the Homosassa River Estuary segment is meeting the NNC criteria for TP, TN, and chlorophyll, and is therefore not classified as impaired.

The upper portion of the Homosassa River contained within WBID 1345, is a tidal freshwater segment and therefore is exempt from NNC criteria development, per Rule 62-302.400, F.A.C., which states "numeric values…for nutrient and nutrient response values do not apply…to tidal tributaries that fluctuate between predominantly marine and predominantly fresh water during typical climatic and hydrologic conditions."

3.1.4 Total Maximum Daily Loads (TMDL)

Section 303(d) of the federal Clean Water Act requires states to submit to the U.S. Environmental Protection Agency a list of surface waters that do not meet applicable water quality standards (impaired waters) and establish a TMDL for each pollutant causing the impairment. A TMDL is the amount of a certain pollutant that a receiving water body can assimilate without causing violation of a pollutant-specific water quality standard. All TMDLs are site-specific criteria and apply to identified WBIDs. Exceeding a TMDL value constitutes exceeding the criteria for the identified WBID. A TMDL must be developed for waterbody segments placed on FDEP's Verified List of Impaired Waters. Once a TMDL has been adopted, the WBID for which the TMDL applies is then removed or “delisted” from the verified list of impaired waters. Delisting a WBID does not imply that the WBID is no longer impaired.

In 2012, several of the springs discharging to the Homosassa River were placed on the verified impaired list for Nutrients based on presence of algal mats. Nitrate nitrogen was determined by the DEP to contribute to the ecological imbalance of several springs that discharge into the Homosassa River (Bridger et al. 2014). The presence of filamentous algal mats in the spring pools was the primary line of evidence for this imbalance (Bridger et al. 2014). Based on laboratory studies (Stevenson et al. 2007; Stevenson et al. 2004) and other nutrient algae studies (Bridger et al. 2014), the FDEP adopted a TMDL nitrate concentration of 0.23 mg/L for the following springs: Bluebird Springs (WBID 1348A), Hidden River Springs (1348E), and Homosassa-Trotter-Pumphouse Springs Group (WBID 1345G). Currently none of the springs listed are meeting the TMDL.

It is important to note that the nitrate TMDL is based solely on the relationship between nitrogen and filamentous algae and not phytoplankton algae which can also increase in biomass with increasing anthropogenic nutrient enrichment (DEP 2013). However, chlorophyll-nutrient relationships in tidal spring fed estuaries like the Homosassa River System are extremely complex and very difficult to detect. Traditionally, nitrogen has been viewed as the predominant limiting nutrient in marine waters. However, there are many exceptions to this traditional view, particularly in coastal ecosystems, where such generalizations have limited practical meaning for water management (Frazer et al. 2002).

3.2 Overview of Water Quality Data Sources

Multiple water quality datasets are available for the Homosassa River System, but differences in sampling location, sampling frequency, and laboratory procedures used for their development made it difficult to combine them. This section summarizes sources of water quality and other data types used for this minimum flow reevaluation. A quality control data screening procedure was employed (Janicki Environmental, Inc. and WSP, Inc. 2018) to identify any potential anomalous values in each assessed dataset. While anomalous data points were identified, no data were eliminated from the database that was developed based on the screening procedures. A Microsoft Access database was created of all available water quality, hydrologic, and other available ancillary datasets compiled for the Homosassa River.

3.2.1 Active Water Quality Data Collection

Ongoing, active water quality sampling networks include three District projects: Coastal Rivers Project P108, COAST Project P529, and Spring Vents Project P889 (Table 3-2). Since 2016, the District has also deployed continuous recording devices at three locations along the Homosassa River. Continuous recorders collect a limited suite of water quality data at 15-minute to one-hour intervals and transmit these data remotely via cellular transmission. This gives the District the ability to monitor certain water quality parameters across diurnal and tidal cycles, and during storms and other significant events.

Surface-water stations sampled as part of the District's Coastal Rivers Project P108 sampling program are shown in Figure 3-2. Sampling began in late 2005 and included bimonthly sampling until 2011 after which sampling switched to a quarterly frequency. Coastal Rivers Project P108 samples are grab samples colleted by District staff and analyzed at the NELAC-certified District water chemistry laboratory in Brooksville, FL for the standard District suite of laboratory analytes (Table 3-3). Several field, or in-situ, water quality parameters are also collected concurrently with grab sample collection.

COAST Project P529 began in 1997 as a District-funded University of Florida project to monitor potential impacts of increased nitrogen loading from springs to the nearshore coastal waters of the Springs Coast, extending from Waccasassa Bay southward to Anclote Key (Jacoby et al. 2015; Jacoby et al. 2012). Originally, there were 50 stations sampled along the Springs Coast monthly for a limited suite of field and laboratory parameters by the University of Florida between 1997 and 2010. In 2013, the District resumed water quality monitoring for a subset of the original 50 stations and expanded the suite of water quality parameters to match the standard District suite for the Coastal Rivers Project P108 network (Figure 3-3). For the Homosassa River, there were 10 fixed stations sampled until 2010. In 2013, the District resumed sampling on a quarterly basis seven of the original ten stations.

The District has been collecting water quality data in springs since the early 1990s in response to concerns about increasing nitrate concentrations (Jones et al. 2011). The principal spring vents of the Homosassa River have been monitored by the District since 1993. There are eleven active spring vents sampled under the Spring Vents Project P889 (Figure 3-4). Spring vent samples are collected at or near low tide by using a sampling pump attached to a tube set into the spring vent. In some springs, for example, Homosassa 1, 2, and 3, sample tubes have been permanently installed by cave divers to ensure that the sample collected is representative of the water chemistry from the individual spring vent. The standard District suite of water quality parameters for the Spring Vents Project P889 is based on the suite of groundwater quality parameters (Table 3-4) and differs slightly from the suite of surface water parameters (Table 3-3).

Since 2017, the District has been collecting continuous water quality data at three locations on the Homosassa River (Figure 3-5). Despite having a short period of record, these recorders have collected an enormous amount of data at hourly sampling intervals. Continuous recorders have a relatively limited, though ecologically important, parameter suite (Table 3-5). In addition to the District's continuous recorders, the United States Geological Survey through a joint funding agreement with the District has a continuous nitrate sensor deployed at the Homosassa Springs at Homosassa Springs FL gage located near the headsprings (Figure 3-5).

Table 3-2. Active District water quality monitoring networks. From 1996 – 2010, COAST Project P529 was a District-funded University of Florida project. The District resumed sampling a subset of the original stations in 2013 on a quarterly basis and added several water quality parameters.

Monitoring Network	Period of Record	Annual Sampling Frequency	Number of Sampling Events
Coastal Rivers Project P108	2005 – 2017	Bi-monthly /quarterly after 2011	65
COAST Project P529	1996 – 2017	Monthly/quarterly after 2013	140
Spring Vents Project P889	1993 – 2017	Quarterly	120

Figure 3-2. Active surface-water sampling locations for the Coastal Rivers Project P108 monitoring network and location of the District's three continuous recorder stations.

Table 3-3. Standard District suite of field and laboratory surface water quality parameters for Coastal Rivers Project P108 and COAST Project P529 since District resumption in 2013. * denotes field parameters collected in-situ concurrent with grab sample collection.

Parameters	
Ammonia (N) (Total)	pH (Total)*
Calcium (Dissolved)	Phaeophytin (Total)
Chlorophyll a (Total)	Phosphorus- Total (Total)
Color (Dissolved)	Potassium (Dissolved)
Depth (Total)*	Residues- Nonfilterable (TSS) (Total)
Depth, bottom (Total)*	Residues- Volatile (Total)
Dissolved Oxygen (Total)*	Salinity (Total)*
Iron (Dissolved)	Secchi-horizontal (Total)*
Magnesium (Dissolved)	Secchi-vertical (Total)*
Nitrate-Nitrite (N) (Total)	Sodium (Dissolved)
Nitrite (N) (Total)	Specific Conductance (Total)*
Nitrogen- Total (Total)	Temperature (Total)*
Orthophosphate (P) (Dissolved)	Turbidity (Total)

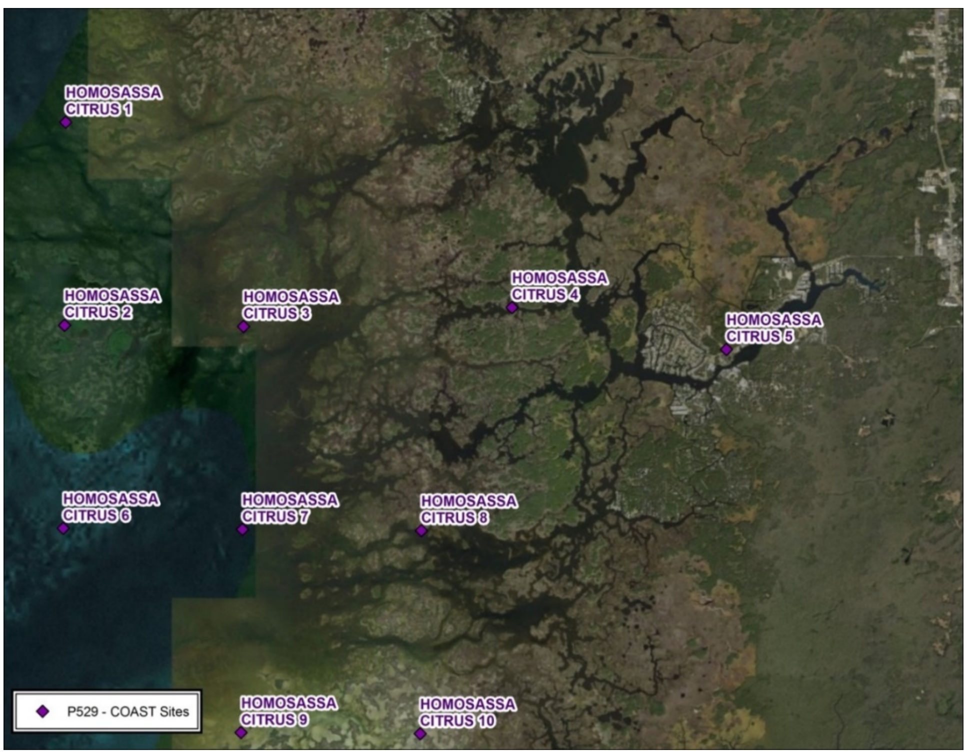


Figure 3-3. COAST Project P529 sample locations. Ten stations were originally sampled until 2010 for a limited suite of water quality parameters. In 2013, the District expanded the suite of parameters and resumed sampling at Homosassa Citrus 1, 2, 3, 4, 6, 7, and 8. The District continues to actively collect water quality at these locations on a quarterly basis.

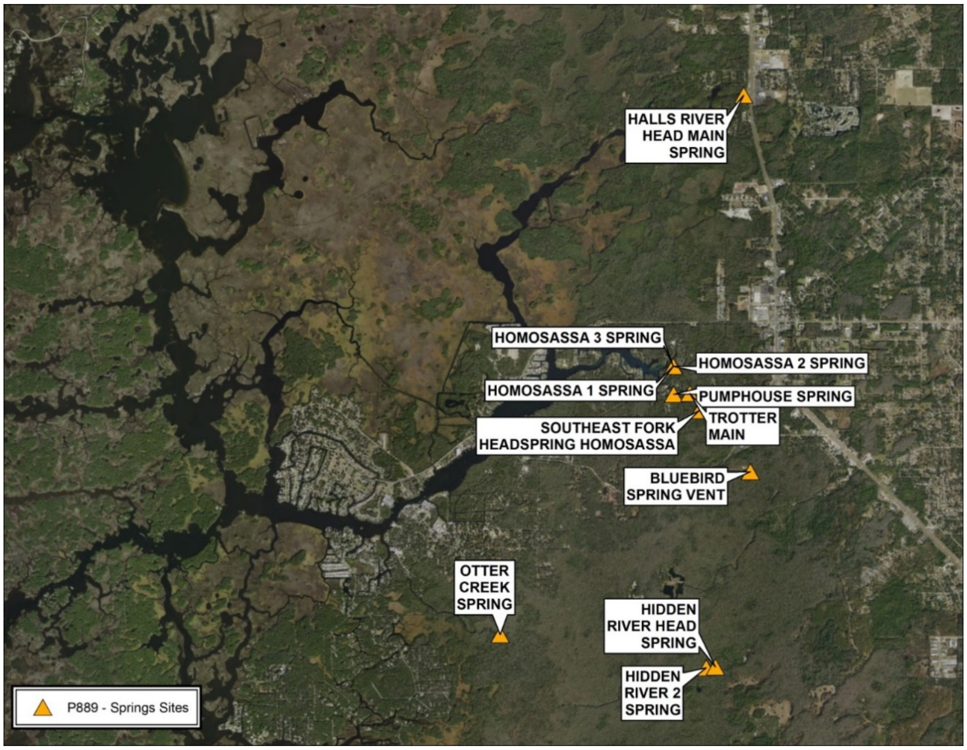


Figure 3-4. Active spring vent sampling locations for the Homosassa River under the District's Spring Vents Project P889.

Table 3-4. Standard District groundwater parameters for Spring Vents Project P889. * denotes field parameters collected in-situ concurrent with grab sample collection.

Parameters	
Alkalinity (Total)	Nitrogen- Total (Total)
Aluminum (Dissolved)	Orthophosphate (P) (Dissolved)
Ammonia (N) (Total)	pH (Total)*
Boron (Dissolved)	Phosphorus- Total (Total)
Calcium (Dissolved)	Potassium (Dissolved)
Carbon- Total Organic (Total)	Residues- Filterable (TDS) (Dissolved)
Chloride (Dissolved)	Silica – Dissolved (Dissolved)
Color (Dissolved)	Sodium (Dissolved)
Dissolved Oxygen (Total)*	Specific Conductance (Total)*
Fluoride (Dissolved)	Strontium (Dissolved)
Iron (Dissolved)	Sulfate (Dissolved)
Magnesium (Dissolved)	Temperature (Total)*
Manganese (Dissolved)	Turbidity (Total)
Nitrite (N) (Total)	

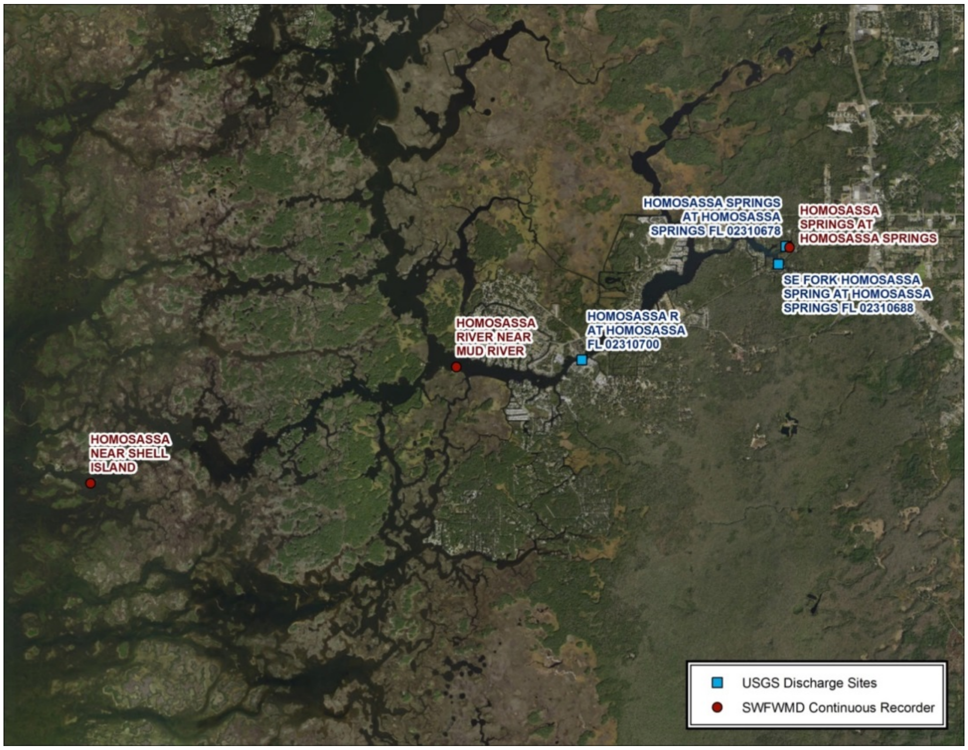


Figure 3-5. Location of the three District continuous recorders (red circles) for water quality on the Homosassa River. Blue squares show the locations of the USGS river discharge gages. The most upstream USGS gage – Homosassa Springs at Homosassa Springs, FL (No. 02310678) – also has a continuous nitrate sensor.

Table 3-5 Parameters measured at the continuous recorders at Homosassa River Near Mud River and Homosassa Near Shell Island stations.

Parameters	
Temperature	fDOM
Depth	Chlorophyll
Conductivity	Turbidity
pH	Salinity
Dissolved Oxygen (mg/L and %)	Nitrate
Light Spectrum	Dark Spectrum

3.2.2 Inactive Water Quality Data Collection

In addition to data for active, ongoing water quality monitoring described in Section 3.2.1, data are available for a variety of water quality stations previously sampled in the Homosassa River. Of particular note was the University of Florida 5 Rivers Project, a District-funded, spatially intensive water quality and biological monitoring study conducted by the University of Florida (Frazer et al. 2001) between August 1998 and November 2011 (with a gap between 2001 and

2003). The University of Florida 5 Rivers Project was a multi-year research project on five rivers along Florida's Springs Coast: the Weeki Wachee, Chassahowitzka, Homosassa, Crystal and Withlacoochee rivers. The general objective of the project was to describe quantitatively the physical, chemical and vegetative characteristics of each of the rivers (Frazer et al. 2001). Since the first report in 2001, other reports have been published using these transect data (Frazer et al. 2006; Frazer et al. 2002). For the Homosassa River, 20 transects were established along the length of the river (Figure 3-6), with three sampling points per transect for the 15 upstream transects and a single sample for the 5 most downstream transects. Both field and a limited suite of water quality parameters (Table 3-6) were collected (with a total of approximately 138 samples per transect over the study period.

In addition to the University of Florida 5 Rivers Project stations, several other inactive stations and associated data exist for the Homosassa River (Figure 3-7). These stations are of limited use here because of their relatively small sample sizes, especially when compared to the spatially and temporally intense University of Florida 5 Rivers Project and the active District sampling networks described in the previous section.

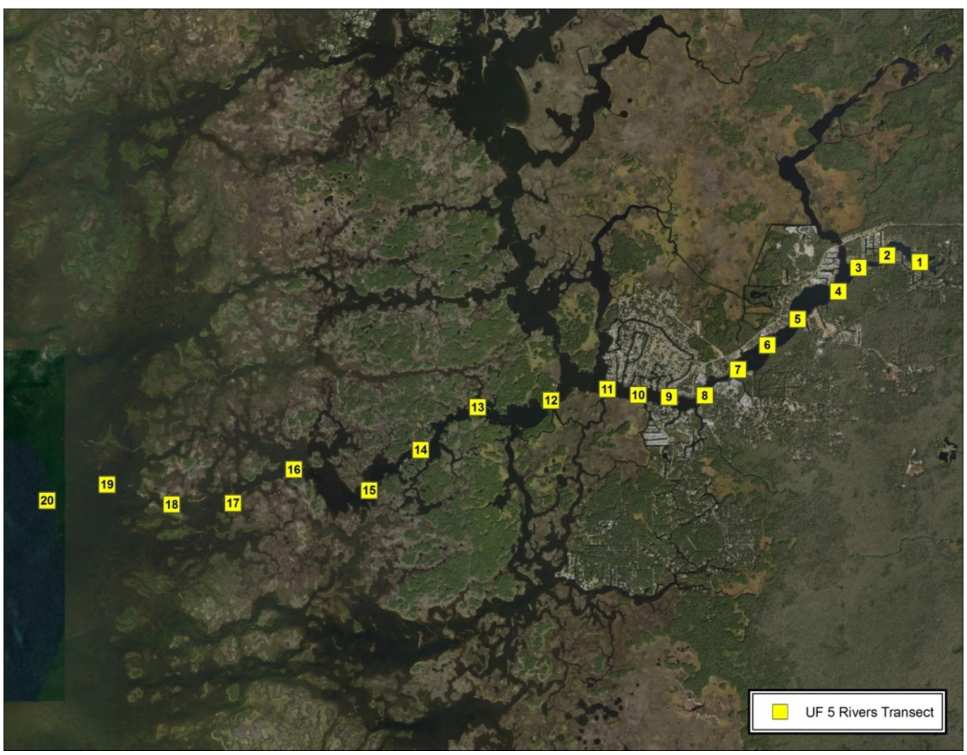


Figure 3-6. The inactive University of Florida 5 Rivers Project transect locations on the Homosassa River.

Table 3-6. Water quality parameters for the University of Florida 5 Rivers Project.

Parameters	
Alkalinity (Total)	Specific Conductivity
Chlorophyll a	Soluble Reactive Phosphorous
Color	Temperature
Dissolved Oxygen	Total Nitrogen
Ammonium	Total Phosphorous
Nitrate	pH
Salinity	

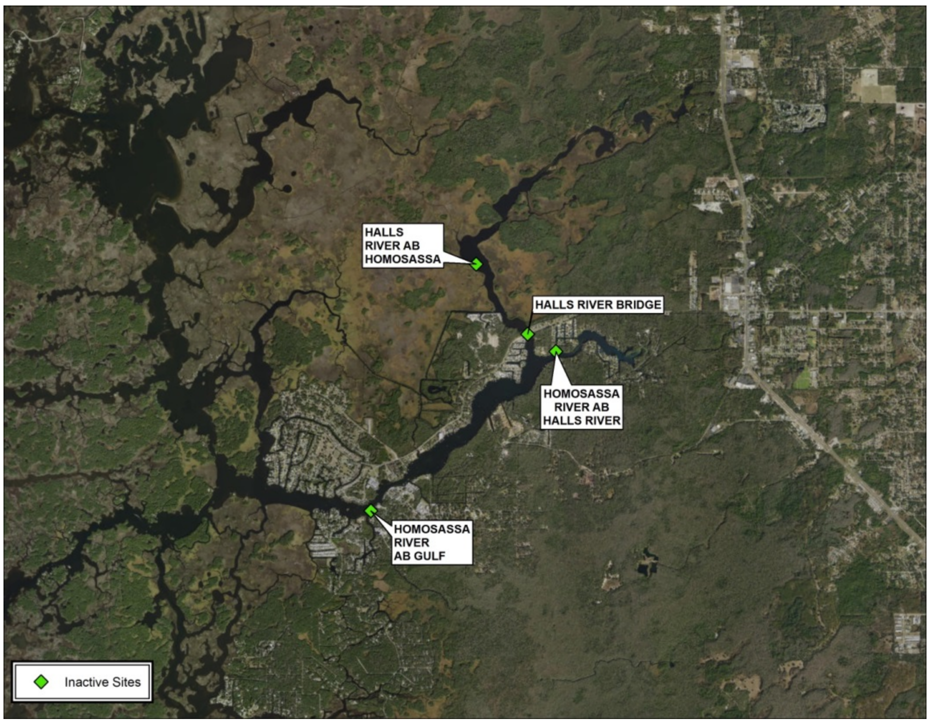


Figure 3-7. Inactive water quality monitoring stations on the Homosassa River other than those for the University of Florida 5 Rivers Project shown in Figure 3-6. These four stations have a limited period of record and were sampled by the District for the FDEP's STORET monitoring network.

3.3 <u>Spatial Variation in Water Quality Constituents</u>

This section summarizes the spatial variation in select water quality constituents for the Homosassa River and estuary system. The University of Florida 5 Rivers Project transect data from 1998 to 2011 are presented here because of their high spatial resolution. The 20 sites, or transects, were located at approximately 0.5 km intervals along the main stem of the river (Figure 3-8). Details of the sampling design and in-depth results and discussion from the University of

Florida 5 Rivers Project can be found in Frazer et al. (2001, Frazer et al. 2006). Additionally, data from the five Coastal Rivers Project P108 (Figure 3-2) and select COAST Project P529 (Figure 3-3) fixed stations are also presented here to include more recent data.

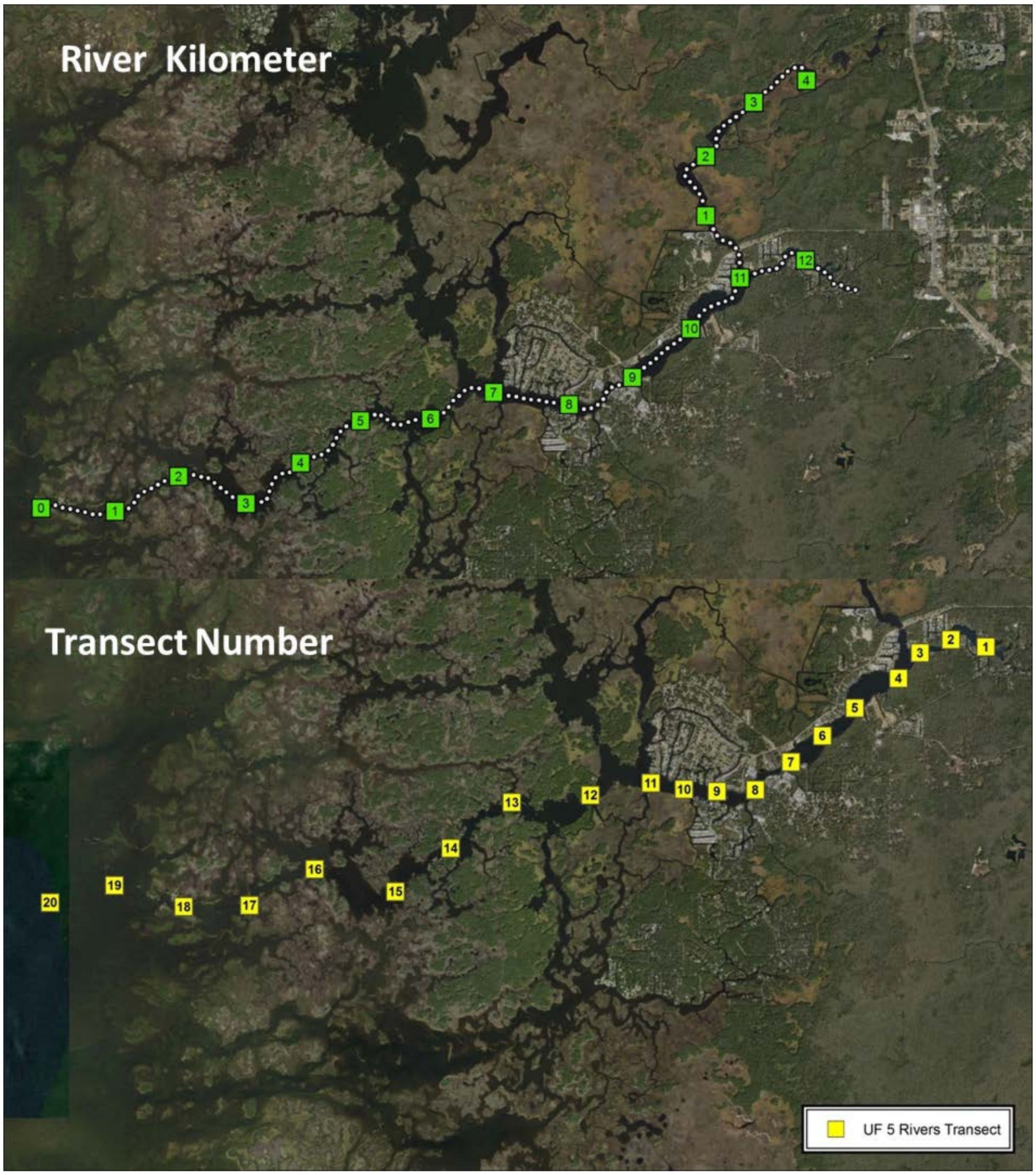


Figure 3-8. River kilometer (Rkm) numbering system and the Univeristy of Florida 5 Rivers Project transect station locations for the Homosassa River.

3.3.1 Total Nitrogen

Nitrogen occurs in water as nitrite or nitrate anions (NO2- and NO3-), in cationic form as ammonium (NH4+), and at intermediate oxidation states as a part of organic solutes (Hem 1986). Total nitrogen is the sum of inorganic and organic nitrogen species. For the Homosassa River System, data from the active Coastal Rivers Project P108 network shows a decrease in total nitrogen concentrations within the first 5 kilometers (Rkm 7.8) downstream of the headsprings (Figure 3-9). Further downstream, total nitrogen concentration continues to decrease but at a much slower rate. Nitrogen dynamics in tidal freshwater and estuarine systems are complex and there are many reasons for this longitudinal pattern. Water column nitrogen is a function of internal nitrogen cycling across the sediment-water interface, uptake by benthic primary producers, loss of nitrogen through dilution with Gulf coastal waters, and loss of nitrogen through denitrification.

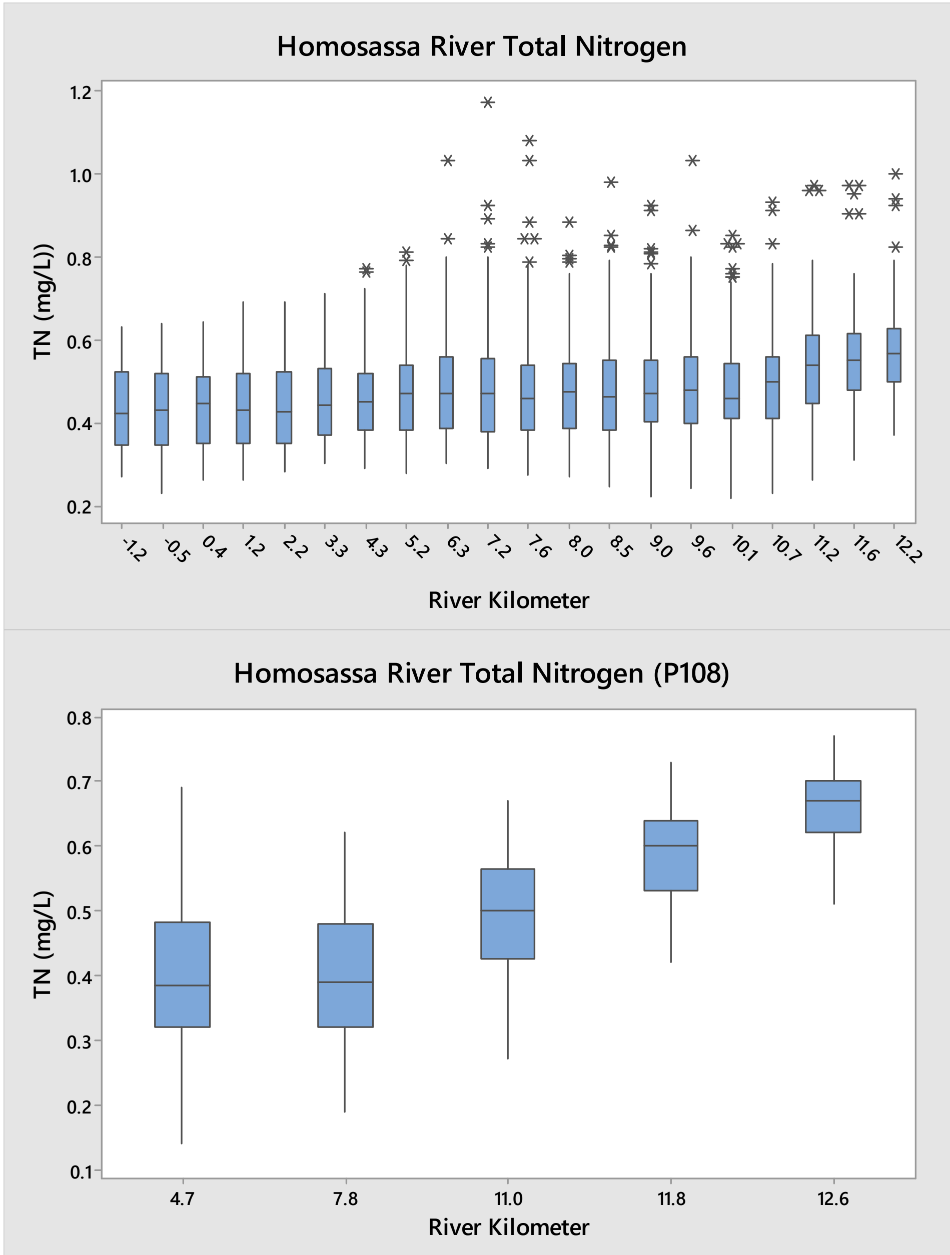


Figure 3-9. Distribtuon of total nitrogen concentrations from the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011 and from the active Coastal Rivers Project P108 data collection effort between 2005 and 2017. Boxes represent the interquartile ranges and stars represent outliers.

3.3.2 Nitrate + Nitrite

In the water column, inorganic nitrogen is mostly in the form of nitrate (NO_3^-) but can also occur as nitrite (NO_2^-) though in much lower concentrations. In fact, nitrite is seldom present in concentrations large enough to influence ionic balance to a noticeable degree (Hem 1986). For brevity, the terms “nitrate,” “nitrate + nitrite,” “NO3,” and “NOX” can be used interchangeably. Because nitrate is an inorganic form of nitrogen, it is readily available for uptake by phytoplankton and submerged aquatic vegetation (SAV) including benthic and epiphytic algae, and to a lesser extent, seagrass. Increases in ambient concentrations of nitrate from anthropogenic sources including fertilizer and wastewater can lead to increases in unwanted algal growth, and in high enough concentrations, can lead to eutrophication.

There are strong longitudinal gradients in nitrate along the Homosassa River (Figure 3-10). Nitrate concentrations are greatest near the headsprings and decline rapidly within the first kilometer of the river then continue to gradually decrease to near laboratory detection limits close to the mouth of the river.

Nitrate concentrations decline much more rapidly with distance from the headsprings than total nitrogen (Figure 3-11). This difference is likely caused by the transformation of inorganic nitrate to organic nitrogen by phytoplankton algae suspended in the water column. Total nitrogen concentrations at the head springs are almost entirely in the form of inorganic nitrogen, namely nitrate. Virtually all nitrates are removed from the water column near the mouth of the river (Rkm 0). Therefore, almost all of the nitrogen being exported to the nearshore coastal waters is organic nitrogen not inorganic nitrate.

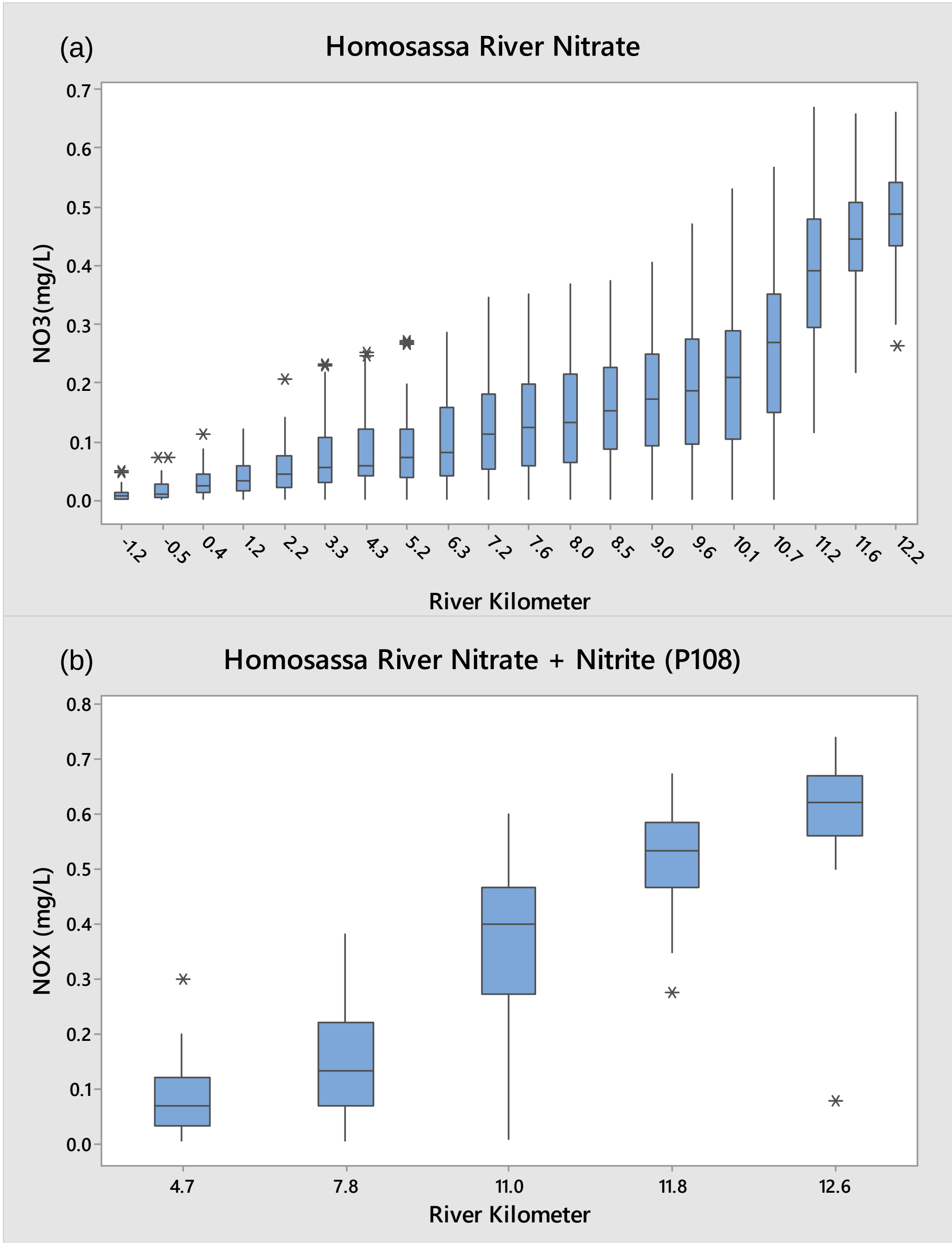


Figure 3-10. Distribtuon of nitrate concentrations from (a) the University of Florida 5 Rivers transect data collection effort between 1998 and 2011, and (b) the Coastal Rivers Project P108 active water quality sampling network between 2006 and 2017. Boxes represent the interquartile ranges and stars represent outliers.

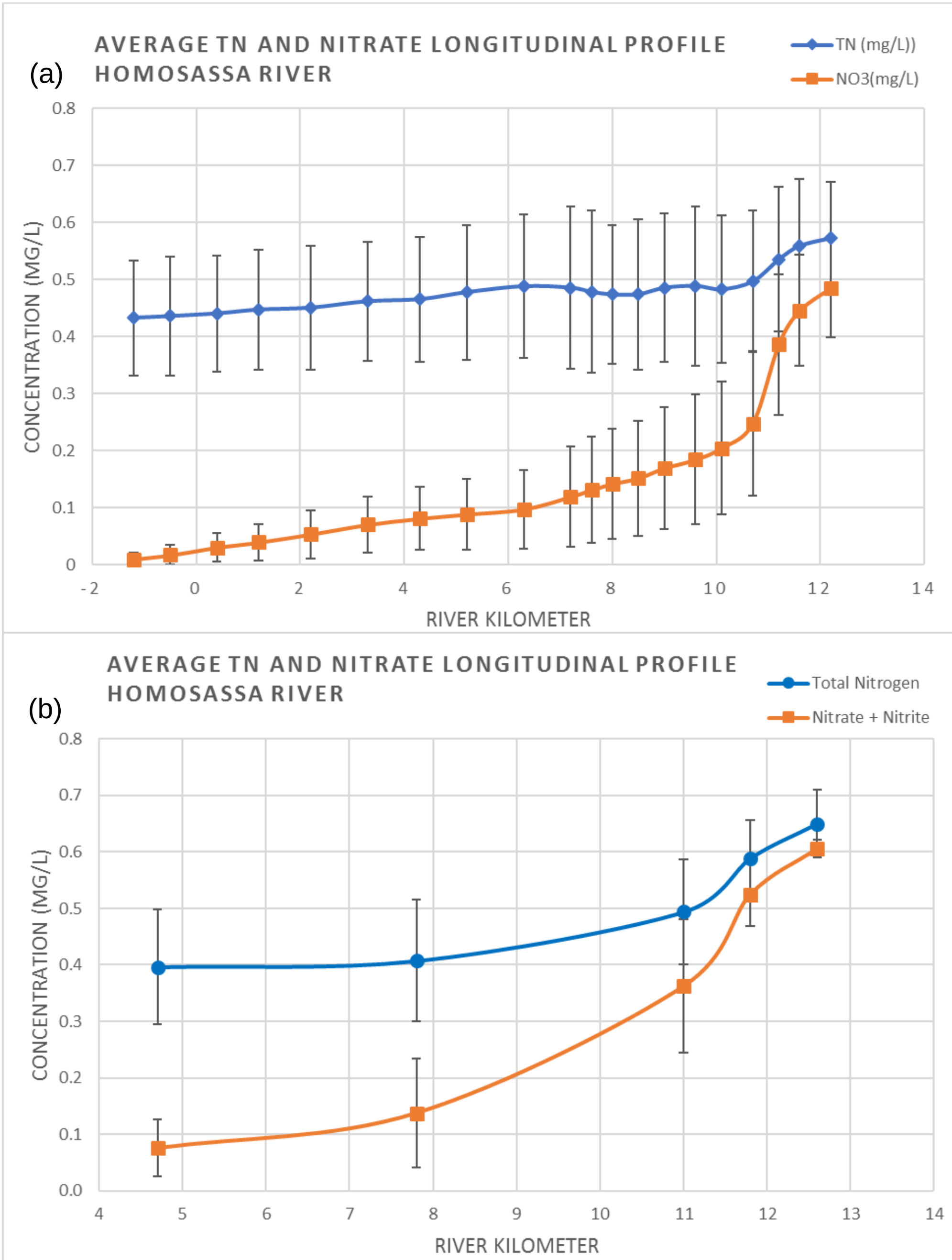


Figure 3-11. Longitudinal profiles of total nitrogen and nitrate concentrations from (a) the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011, and (b) the Coastal Rivers Project P108 active water quality sampling network between 2006 and 2017. Error bars represent the standard deviation for each station.

3.3.3 Total Phosphorous

Along with nitrogen, phosphorous is one of the most important nutrients supporting plant growth and often is the nutrient limiting primary production in freshwater and marine systems. Excessive nitrogen loading to estuarine waters can result in phosphorous limitation in systems where nitrogen limitation would be expected (Bianchi 2013). Like total nitrogen, total phosphorous (TP) can be divided into organic and inorganic species. Reactive phosphorous is that fraction of TP that is used to describe the potentially bioavailable phosphorous (Delaney 1998) and is discussed in more detail in the following section.

Longitudinal profiles of TP concentrations in the Homosassa River show a slight increase from the headsprings to approximately 3km (Rkm 7.8) downstream (Figure 3-12). TP concentrations stay relatively consistent within the middle section of the river and decline sharply from approximately Rkm 6 to where the river flows into the Gulf of Mexico. This region of TP decline follows the transition from tidal fresh to marine waters.

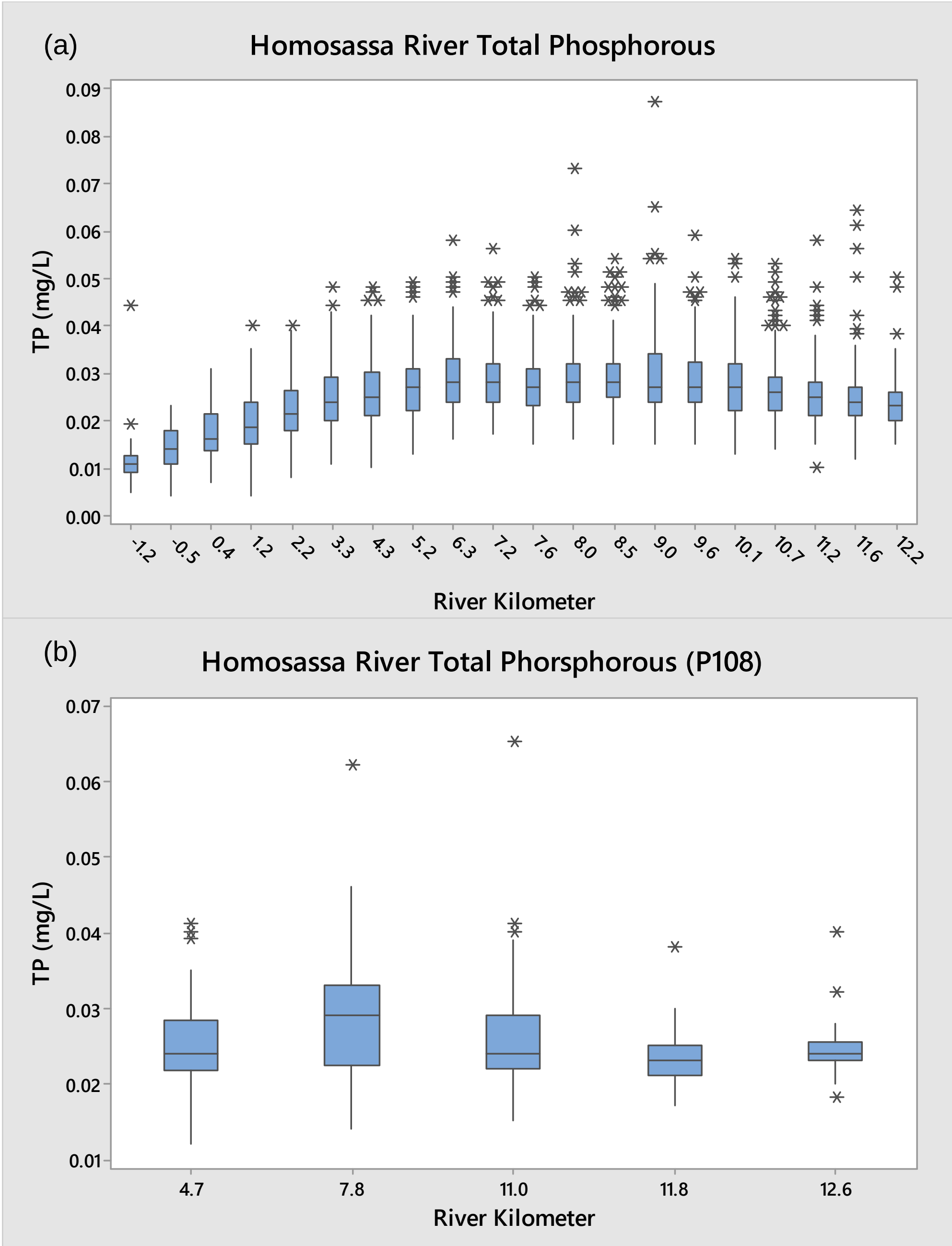


Figure 3-12. Distribtuon of total phosphorous concentrations from (a) the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011, and (b) the Coastal Rivers Project P108 active water quality sampling network between 2006 and 2017. Boxes represent the interquartile ranges and stars represent outliers.

3.3.4 Soluble Reactive Phosphorous and Orthophosphate

Soluble reactive phosphorous (SRP) is characterized as the phosphorous fraction that forms a phosphomolybdate complex under acidic conditions (Strickland and Parsons 1972). A significant fraction of SRP is in the form of orthophosphate (Ortho-P). While SRP and Ortho-P are not the same thing, they are proportional to one another and therefore can both be useful in understanding how phosphorous behaves in the water column. SRP concentrations were reported by the University of Florida 5 Rivers Project while Ortho-P is reported by the District for the active Coastal Rivers Project P108 monitoring network. Both SRP and Ortho-P concentrations display similar longitudinal profiles over their respective periods of record (Figure 3-13) characterized by a maximum at the headsprings leading to a sharp decline in concentration within the first 2 kilometers downstream from the headsprings. The University of Florida 5 Rivers Project data shows SRP increase to a second, smaller peak at Rkm 4.3 and then decrease again as the river flows into the Gulf. The Coastal Rivers Project data also shows an initial decrease from the headsprings, followed by an increase to a second, smaller peak at Rkm 4.7.

Through most of the length of the river, total phosphorus levels remain constant, while SRP and Ortho-P decrease sharply from the headsprings to Rkm 10-11 (Figure 3-14). This relationship between total phosphorous and SRP/Ortho-P suggests that a significant portion of bioavailable phosphorous is being utilized in the upper portion of the Homosassa River. Further, the fact that total phosphorous concentrations do not decrease with decreases in SRP/Ortho-P suggests that uptake of SRP/Ortho-P is occurring in the water column, likely by phytoplankton algae and remaining in the water column as total phosphorus (TP).

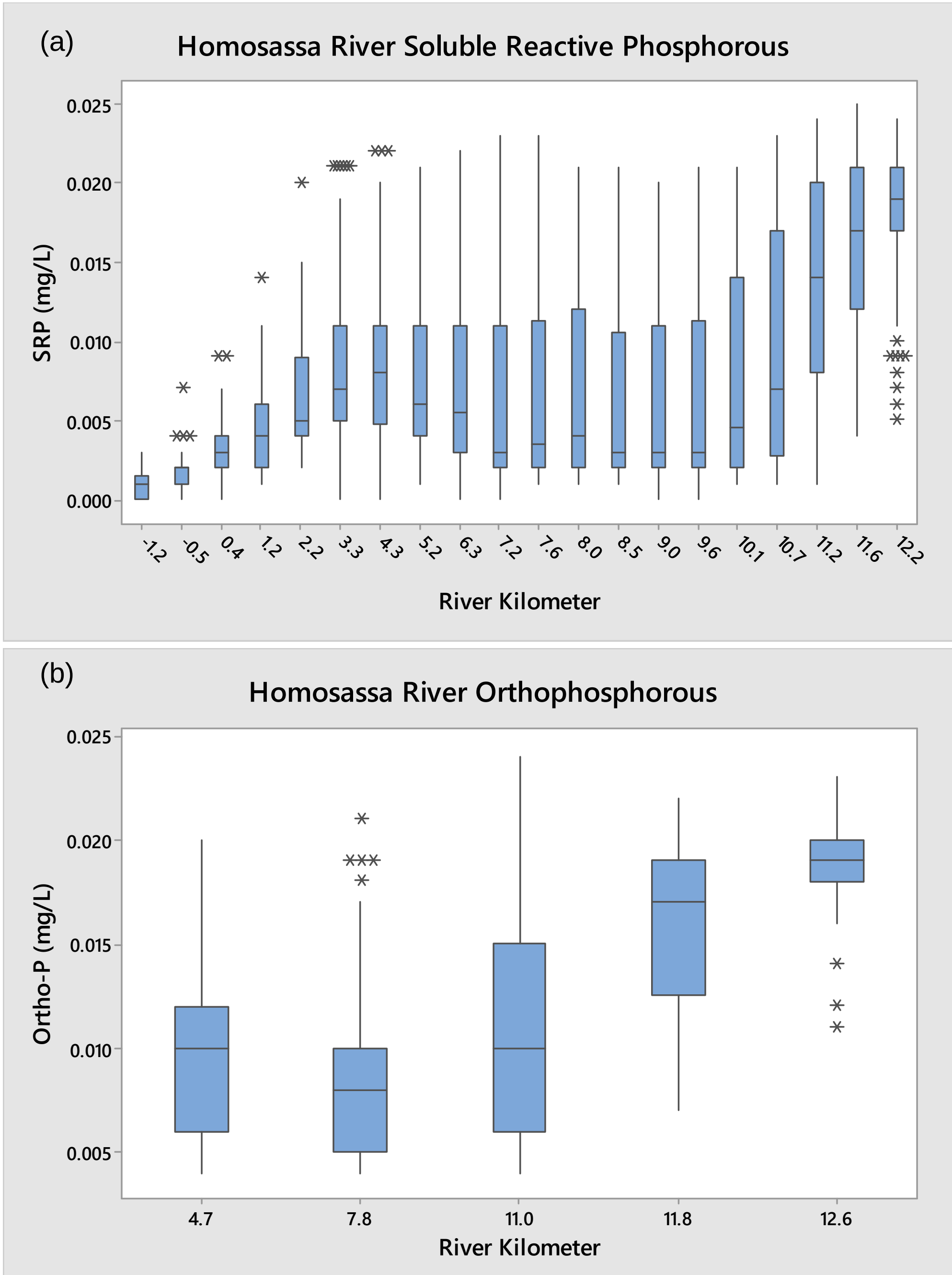


Figure 3-13. Distribtuon of soluble reactive phosphorous concentrations from (a) the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011, and (b) the Coastal Rivers Project P108 active water quality sampling network between 2006 and 2017. Boxes represent the interquartile ranges and stars represent outliers.

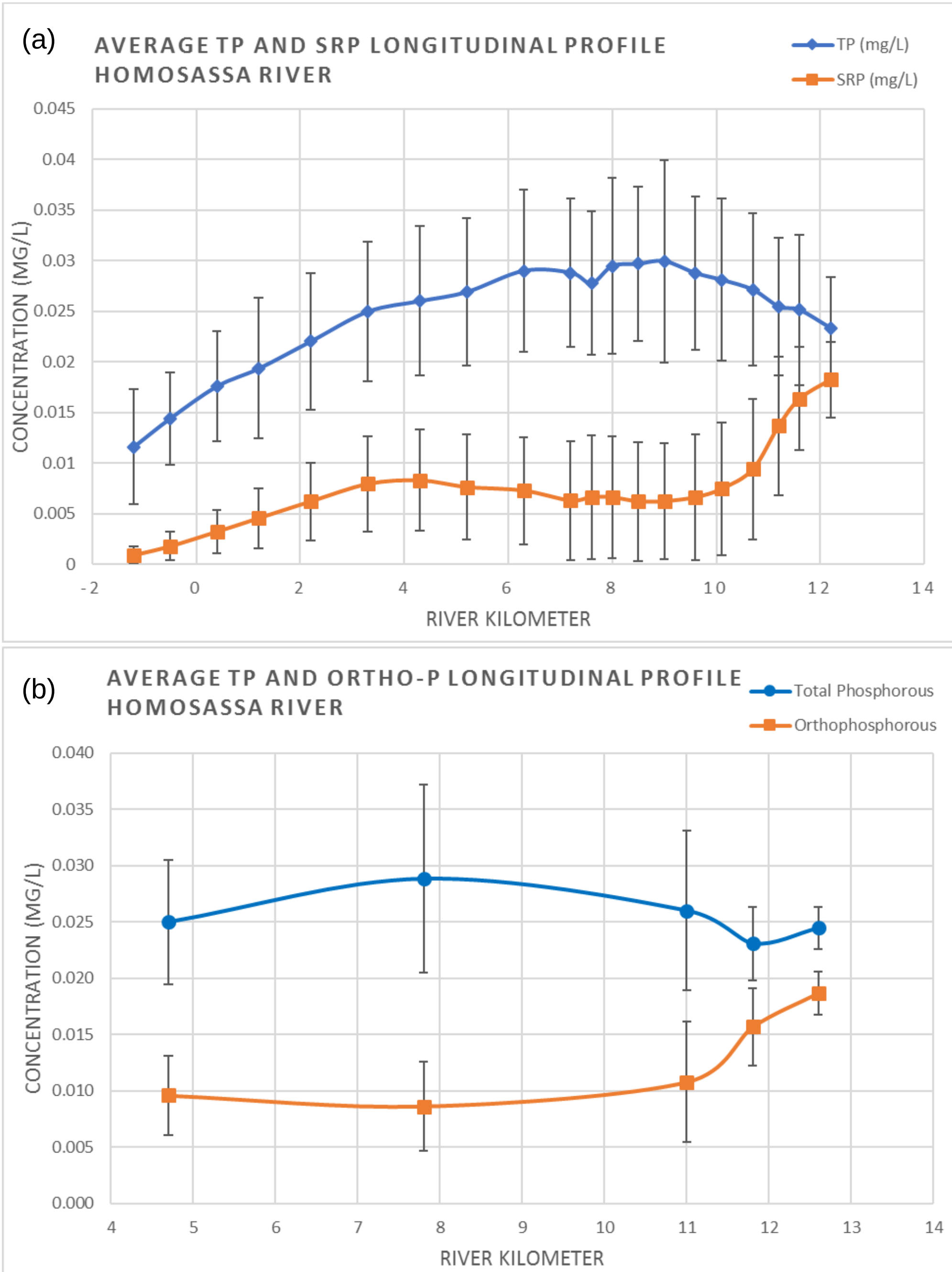


Figure 3-14. Longitudinal profiles of total phosphorous and soluble reactive phosphorous concentrations from (a) the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011 (TOP), and longitudinal profiles of total phosphorous and orthophosphorous from (b) the Coastal Rivers Project P108 active water quality sampling network between 2006 and 2017 (BOTTOM). Note difference in x-axis. Error bars represent the standard deviation for each station.

3.3.5 Chlorophyll

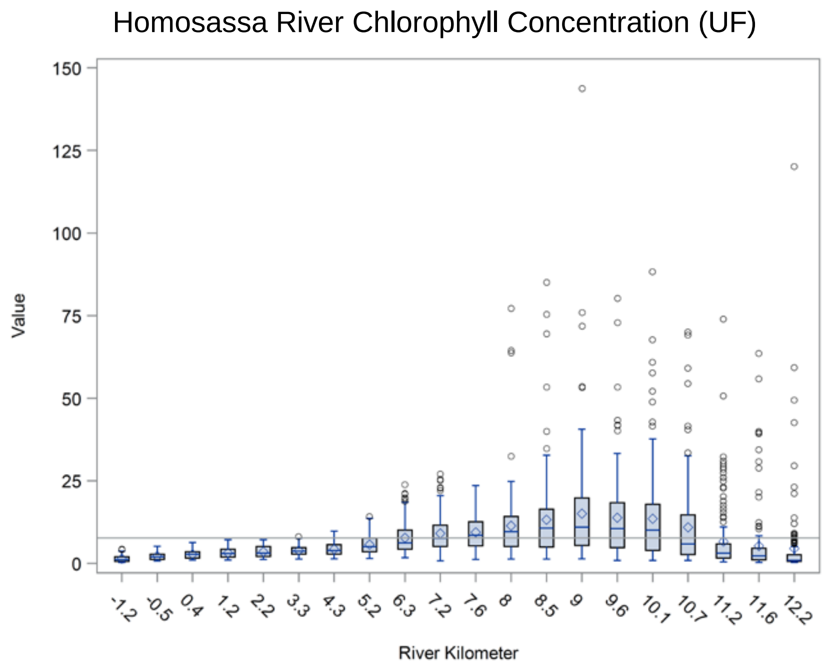
All plants, including algae, contain photosynthetic pigments, the most common being the chlorophylls. Chlorophylls are cyclic tetrapyrrole compounds with a magnesium atom chelated at the center of the ring system (Kirk 1994). There are several types of chlorophylls including chlorophyll *a*, *b*, and *c*. The most abundant of these light harvesting pigments is chlorophyll *a*. For this report, the term "chlorophyll" is used to denote chlorophyll *a* concentration.

Chlorophyll concentration is a useful indicator of phytoplankton biomass, but amongst the various types of algae chlorophyll concentrations vary widely (Kirk 1994). Chlorophyll is also a good predictor of light penetration. Because chlorophyll absorbs light primarily in the blue wavelengths and secondarily in the red wavelengths, green light is reflected and can turn water green at elevated chlorophyll concentrations. Elevated chlorophyll concentrations are often indicative of eutrophic conditions.

Similar longitudinal patterns emerge across both the University of Florida 5 Rivers Project, the active Coastal Rivers Project P108, and COAST Project P529 sampling networks (Figure 3-15). The University of Florida 5 Rivers Project data clearly show the location of a chlorophyll maximum between river kilometer 6.3 and 10. More recent data from the five Coastal Rivers Project P108 stations and the COAST Project P529 stations also capture the chlorophyll maximum despite the lower spatial resolution. This region of consistently elevated chlorophyll concentrations represents an area where high levels of phytoplankton biomass occur. A chlorophyll maximum is a normal feature of tidal freshwater estuaries and represents an area within the estuary of maximum primary productivity (Bukaveckas et al. 2011).

The reasons for the existence of this chlorophyll maximum are complex and are a function of many factors including flow, residence time, and nutrient concentrations (particularly nitrogen and phosphorous). Exploratory data analysis suggests that relationships among chlorophyll, nitrogen, and phosphorous distribution exist (Figure 3-16). Figure 3-16 (B) and (D) suggest that chlorophyll production increases as inorganic nitrogen and soluble reactive phosphorous concentrations decrease. However, extreme caution must be taken not to infer too much from these relationships. There are numerous feedback mechanisms between phytoplankton and nutrient concentrations and many external factors that come into play.

A central objective of the University of Florida 5 Rivers Project transect data collection effort was to investigate the nutrient limitations of five Gulf Coastal rivers and estuaries including the Homosassa (Frazer et al. 2006; Frazer et al. 2002). While elevated concentrations of nitrate nitrogen are a concern, results from the University of Florida 5 Rivers Project indicate that the Homosassa River frequently contains a surplus of phosphorus and nitrogen (Frazer et al. 2002), suggesting phytoplankton may be insensitive to variations in nutrient concentrations. In those instances when nutrients are limiting, previous research in this system and others along the Springs Coast has indicated a strong potential for phosphorus limitation of algal growth rather than nitrogen (Frazer et al. 2006; Frazer et al. 2002). These relationships bear further investigation and are the subject of continued research by the District and other resource management organizations.



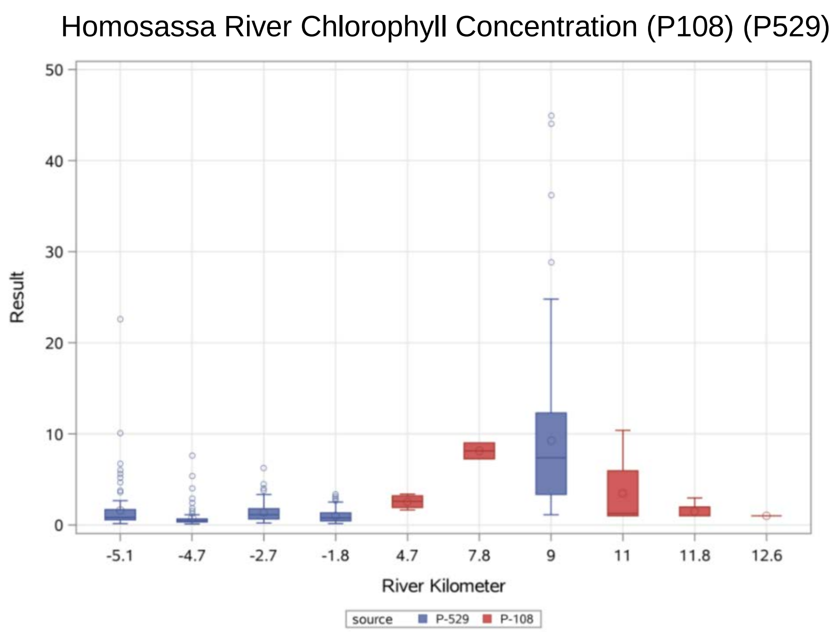


Figure 3-15. Distribtuon of chlorophyll concentrations from the University of Florida 5 Rivers Project (UF) transect data collection effort between 1998 and 2011 and at fixed locations in the Homosassa River from the Coastal Rivers Project P108 and COAST Project P529 active sampling networks in the Homosassa River. Boxes represent the interquartile ranges and stars represent outliers.

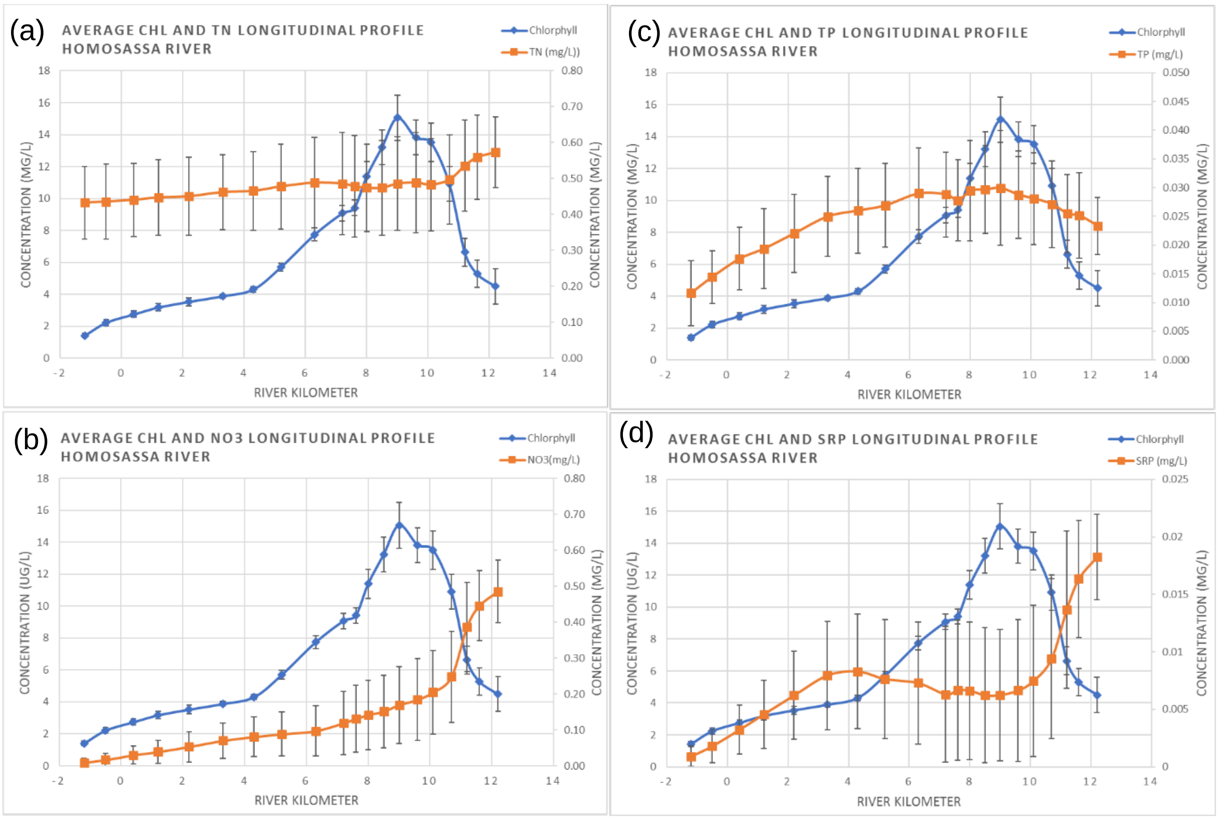


Figure 3-16. Relationship between chlorophyll concentration and various nutrient concentrations from the University of Florida 5 Rivers Project transect data collection effort between 1998 and 2011. (a) (top left) Chlorophyll and total nitrogen, (b) (bottom left) chlorophyll and nitrate, (c) (top right) chlorophyll and total phosphorous, and (d) (bottom right) chlorophyll and soluble reactive phosphorous. Error bars represent the standard deviation for each station.

3.3.6 Water Clarity

For the Homosassa River, much like other spring-fed rivers, water clarity is greatest near the headsprings and then rapidly decreases further downstream. Within the first river mile downstream from the headsprings (including stations CV0, CV0.5, and CV1), clarity decreases by approximately 75% (Figure 3-17). Past CV1, as one traverses toward the mouth of the river (at CV3 and CV5), water clarity is relatively low and less variable than further upstream.

Given this strong longitudinal gradient in clarity, it is important to understand the causes of light attenuation in the water column. Light propagation through the water column is a function of the amount of absorption and scattering in the water column (Kirk 1994). There are three water quality constituents that typically affect clarity: turbidity or total suspended solids (TSS), chlorophyll, and color or colored dissolved organic matter (CDOM). In the Homosassa River, only the TSS and chlorophyll affect water clarity under ordinary conditions. Although colored dissolved organic matter (CDOM) can also affect clarity, color in the Homosassa River is relatively low, often below laboratory detection and has minimal impact on water clarity. On occasion during extreme rain events, CDOM, measured in platinum cobalt units (PCU), can be in sufficiently high quantities to cause the water color to temporarily turn brown.

Phytoplankton is a major attenuator of light via absorption primarily in the blue and red wavelengths. Chlorophyll approximates the abundance of phytoplankton in the water column but can also come from other plant material such as epiphytic and benthic algae suspended in the water column. Regardless of the source, chlorophyll is strongly correlated with Secchi distance in the Homosassa River (Figure 3-18a), Total suspended solids (TSS) are a measure of the amount of material suspended in the water column. For the Homosassa River, TSS also strongly correlates with Secchi distance (Figure 3-18b).

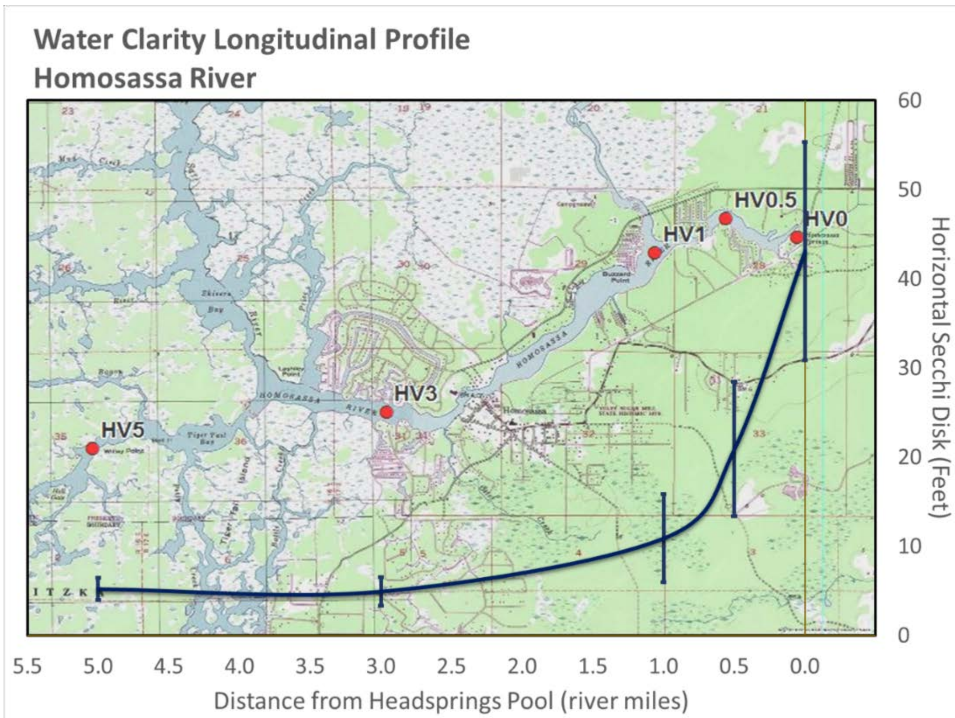


Figure 3-17. Water clarity in the Homosassa River, as measured by horizontal Secchi. Data are from the five active water quality P108 stations HV0 – HV5 (red dots) and are the average over the period 2006-2017. Error bars represent the standard deviation for each station.

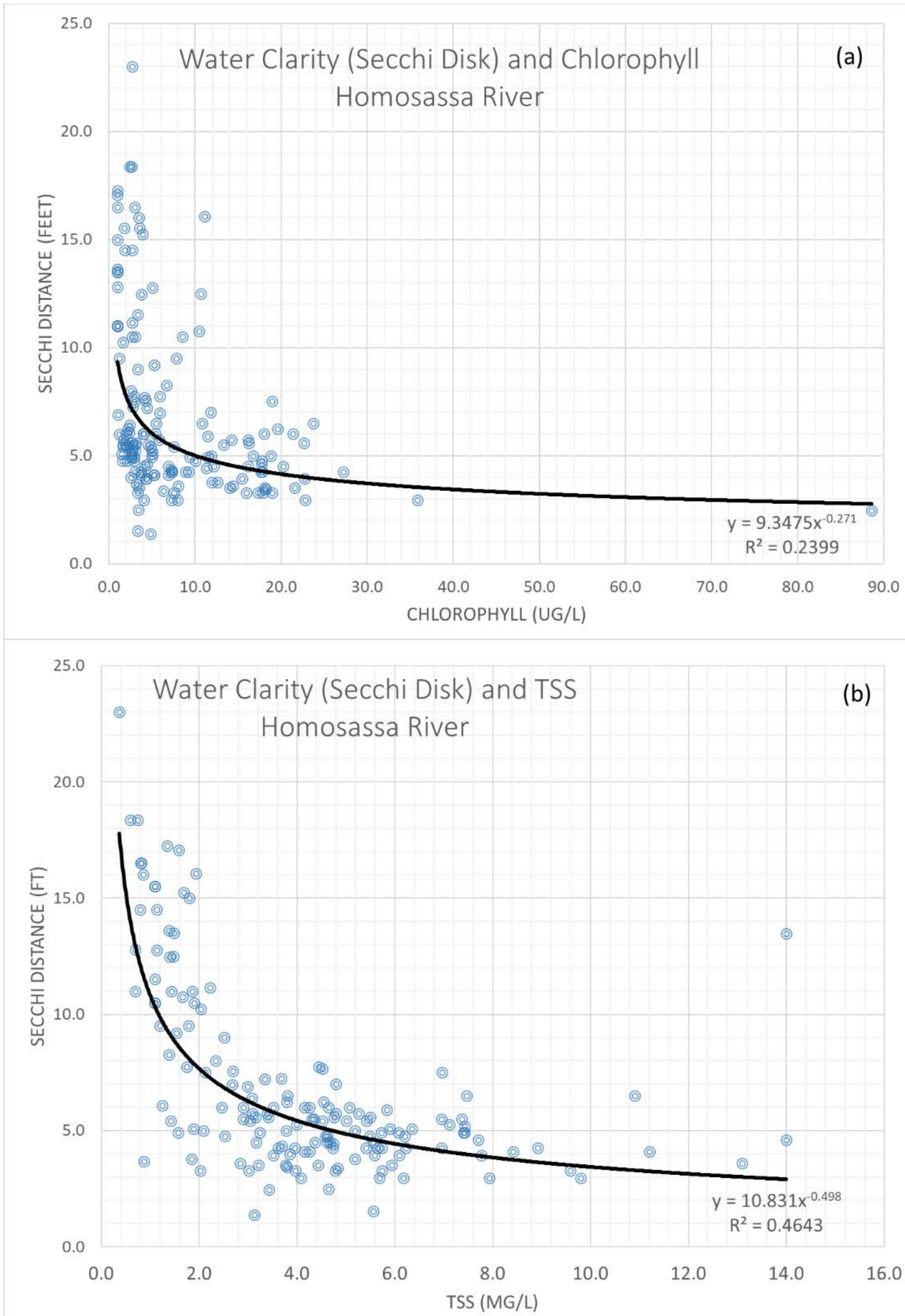


Figure 3-18. The relationships between water clarity as measured by Secchi disk and (a) chlorophyll concentration, and (b) total suspended solids (TSS). Data are from the five Coastal Rivers Project P108 fixed stations for the period 2006-2017. Chlorophyll has a minimum laboratory detection limit of 1.0ug/L and therefore the figure in (a) is truncated at the minimum detection limit.

3.4 Temporal Variation in Water Quality Constituents

This section provides a general description of the temporal variability for selected water quality constituents that may be affected by anthropogenic influences. Data presented here are primarily from locations actively being sampled from the five Coastal Rivers Project P108, COAST Project P529, and the Spring Vents Project P889 fixed stations.

Janicki Environmental, Inc. and WSP, Inc. (2018) evaluated long-term trends by station for all available water quality data using the seasonal Mann-Kendall (SMK) test for trend (Hirsch and Slack 1984; Hirsch et al. 1982) which was developed by the USGS in the 1980s to analyze trends in surface-water quality throughout the United States. More information on these analyses and individual time series plots for each station can be found in Appendix 8.

3.4.1 Total Nitrogen

For the Homosassa River, there is no significant trend in total nitrogen concentration for the period 2006-2017 (Figure 3-19) based on data from all Project P108 stations. Average annual total nitrogen (TN) masks some interesting trends that emerge when total nitrogen concentrations are plotted by Coastal Rivers Project P108 station (Figure 3-20). TN concentrations over this period show increasing trends for the 2 upper-most stations. However, there appears to be no trend at station HV1 (Rkm 11) and slightly decreasing trends at the lower two stations (HV3 and HV5) (Figure 3-20).

Within the Homosassa River Estuary (WBID 1345F), TN concentration has decreased slightly over the past 11 years and at no time during that period has the average total nitrogen concertation exceeded the NNC of 0.51 mg/L (Figure 3-21) in Coastal Rivers Project P108 stations HV3 and HV5.

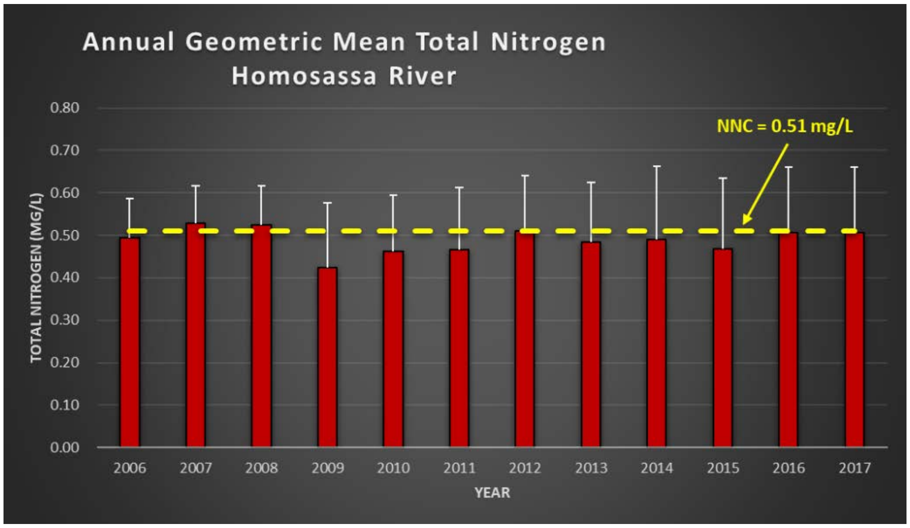


Figure 3-19. River-wide total nitrogen concentration expressed as annual geometric mean for the period 2006 through 2017. Error bars represent the standard deviation for each year. Data are from the five Coastal Rivers Project P108 fixed stations. Yellow dashed line depicts the TN NNC of 0.51mg/L for the Homosassa River WBID 1345F. Annual river-wide total nitrogen is compared with the NNC value for comparison only and not for compliance estimation.

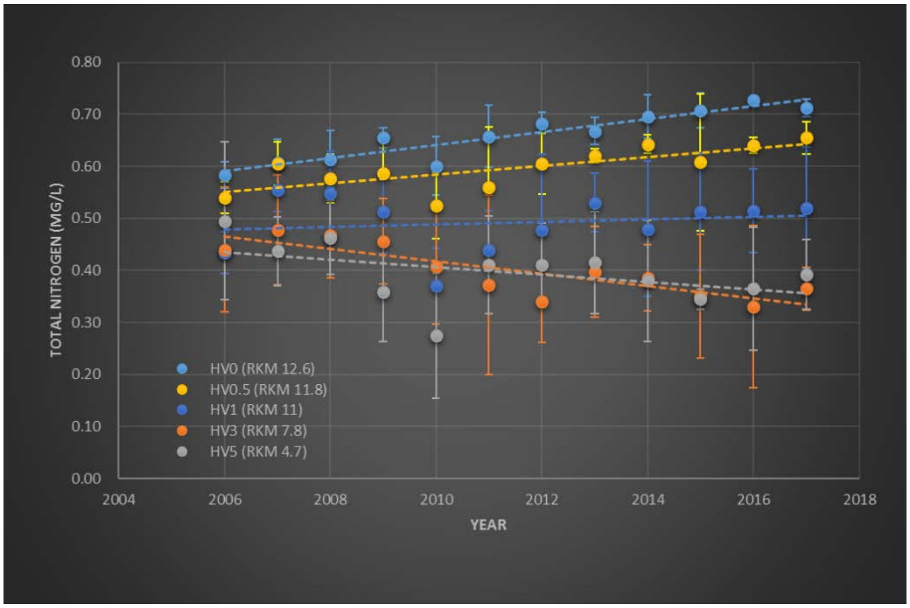


Figure 3-20. River-wide average annual total nitrogen across the period 2006-2017 for the five Coastal Rivers Project P108 fixed water quality monitoring stations. Error bars represent the standard deviation for each year.

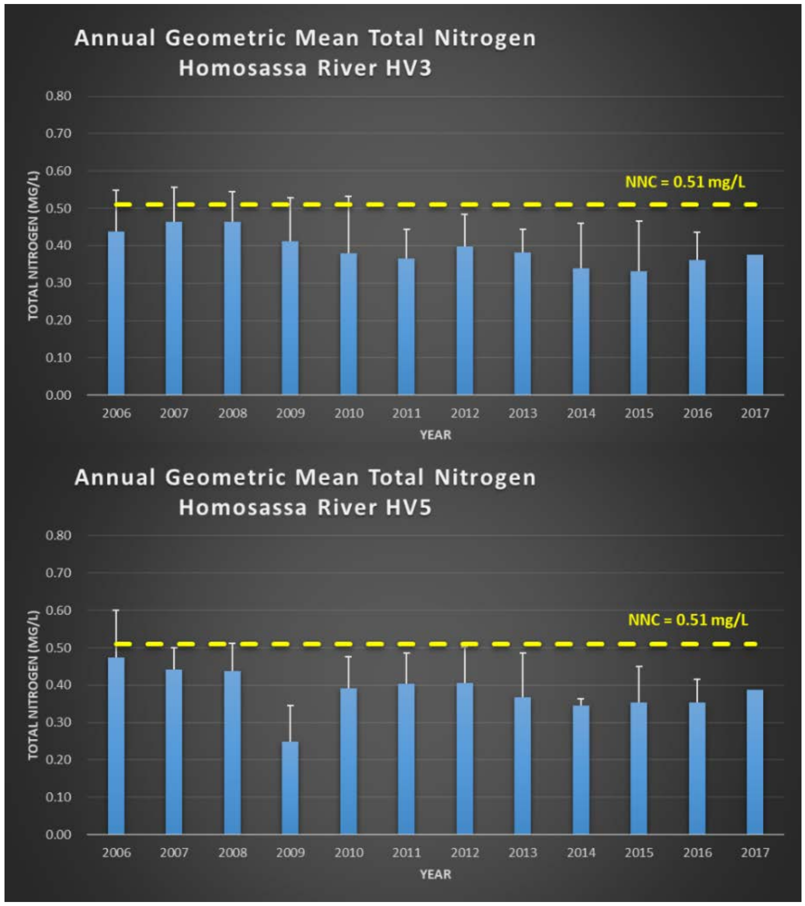


Figure 3-21. Total nitrogen concentration expressed as annual geometric mean for the period 2006 through 2017 for downstream stations HV3 (Rkm 7.8) and HV5 (Rkm 4.7). Error bars represent the standard deviation for each year. Data are from two of the Coastal Rivers Project P108 fixed stations. Yellow dashed line depicts the TN NNC of 0.51 mg/L for the Homosassa River WBID 1345F. Total nitrogen is compared with the NNC value for comparison only and not for compliance estimation.

3.4.2 Nitrate + Nitrite

Elevated concentrations of nitrate continue to be an issue in many of the springs discharging into the Homosassa River. In 2014, the DEP adopted a nitrate TMDL for the Homosassa-Trotter-Pumphouse Springs Group, Bluebird Springs, and Hidden River Springs contained within WBID 1345G, 1348A, and 1348E (Bridger et al. 2014). The nitrate TMDL of 0.23 mg/L was based on the relationship between nitrate and the growth of filamentous algae, namely the freshwater cyanobacteria *Lyngbya wollei* (Bridger et al. 2014). Over the period record beginning in 1994, nitrate concentrations have continued to increase in the Homosassa Springs group, the largest of the spring groups discharging to the Homosassa River (Figure 3-22). Trotter, Pumphouse, Bluebird, and Hidden River Springs exhibit similar temporal trends over time. The DEP is addressing the increasing trends in nitrate through the Basin Management Action Plan (BMAP) process which the DEP considers the blueprint for restoring impaired waters by reducing pollutant loads to meet the established TMDLs.

For the river, nitrate concentrations have increased across the five Coastal Rivers Project P108 stations (Figure 3-23). Relatively large error bars are partially a result of the large range in concentration in nitrate from a peak near headsprings to a minimum near the mouth of the river (Figure 3-10). Because of this strong spatial pattern in nitrate, averaging all five Coastal Rivers Project P108 stations together could mask potential temporal surface water trends.

When the nitrate time series is broken out into individual stations (Figure 3-24), increasing trends in nitrate are evident for the three stations located in the upper kilometer of the river. This mirrors the strong increasing trends in spring vent nitrate (Figure 3-22). As expected, the further downstream stations do not exhibit the same strong trends in nitrate concentrations.

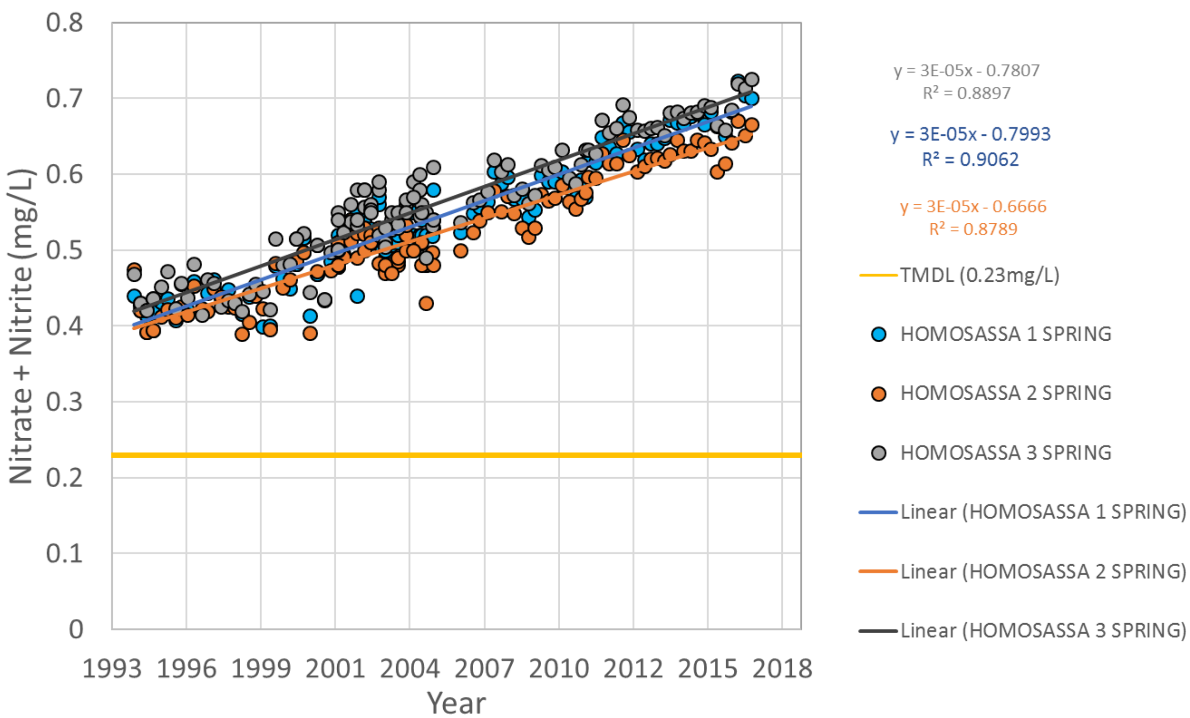


Figure 3-22 Time series of nitrate for the Homosassa Springs group. Homosassa 1, 2, and 3 Springs occur very near one another within the main spring pool at Homosassa Springs State Park. Yellow line represents the TMDL. Data from Spring Vents Project P529.

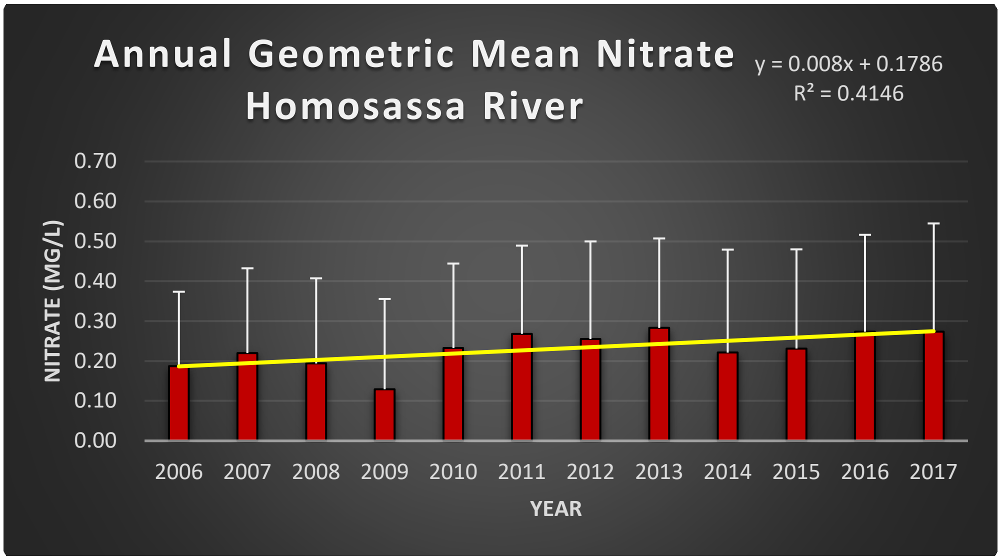


Figure 3-23. River-wide nitrate concentration expressed as annual geometric mean for the period 2006 through 2017. Error bars represent the standard deviation for each year. Data are from the five Coastal Rivers Project P108 fixed stations. Linear regression reveals a significant increasing trend in nitrate concentration over the period (p=0.024, R^2=0.41).

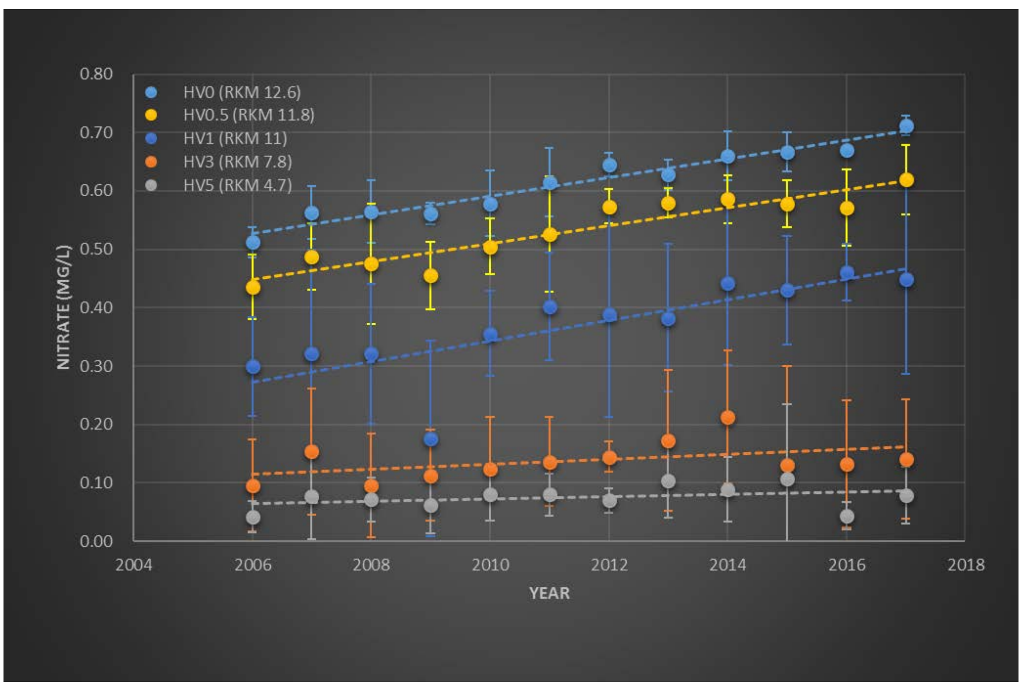


Figure 3-24. Average nitrate concentration by station for the period 2006-2017 for the five Coastal Rivers Project P108 fixed water quality monitoring stations. Error bars represent the standard deviation for each year.

3.4.3 Total Phosphorous

At the 5 Coastal Rivers Project P108 stations in the Homosassa River, phosphorous concentrations have been relatively stable across time from 2006 through 2017 (Figure 3-25). When the total phosphorous time series is broken out into individual stations, slight increase in TP can be seen for station HV3, though the increase is not statistically significant. For the remaining HV stations, TP trend is relatively flat (Figure 3-26).

The lack of obvious temporal trends does not mean that phosphorous is an unimportant water quality indicator. Though much attention has been placed on the potential negative ecological effects of increased nitrogen, phosphorous is an important nutrient affecting the production of phytoplankton in the Homosassa River and throughout the Springs Coast (Frazer et al. 2002). Phosphorous often limits phytoplankton productivity in these surface waters and therefore small increases in phosphorous concentrations could have dramatic effects on phytoplankton production and the initiation of algal blooms. Natural sources of phosphorous in the water column include the sediment and adjacent freshwater and estuarine wetlands. Frazer et al. (2002) reported that in the Homosassa River and estuary, algal growth was phosphorous limited in 51% of experiments, and co-limited by phosphorous and nitrogen in 32% of experiments conducted. Most importantly, Frazer et al. (2002) concluded that in no instance was nitrogen the primary limiting nutrient for algal growth in the Homosassa River. As nitrate concentrations continue to increase in the spring vents of the Homosassa River, it is likely that nitrogen will continue to be in ample supply and phosphorous will continue to be the limiting nutrient for phytoplankton growth.

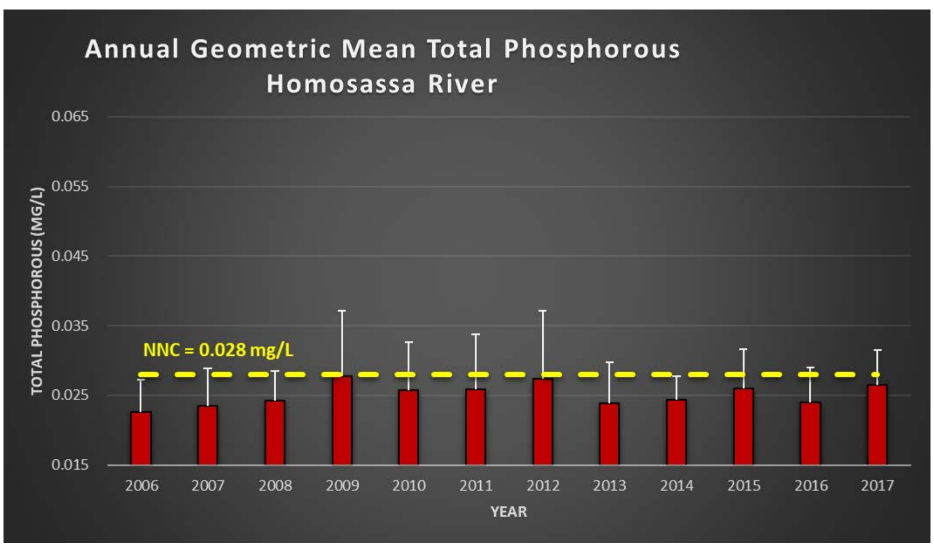


Figure 3-25. River-wide total phosphorous concentration expressed as annual geometric mean for the period 2006 through 2017. Error bars represent the standard deviation for each year. Data are from the five Coastal Rivers Project P108 fixed stations. Yellow dashed line depicts the TP NNC of 0.028 mg/L for the Homosassa River WBID 1345F. Annual river-wide total phosphorous is compared with the NNC value for comparison only and not for compliance estimation.

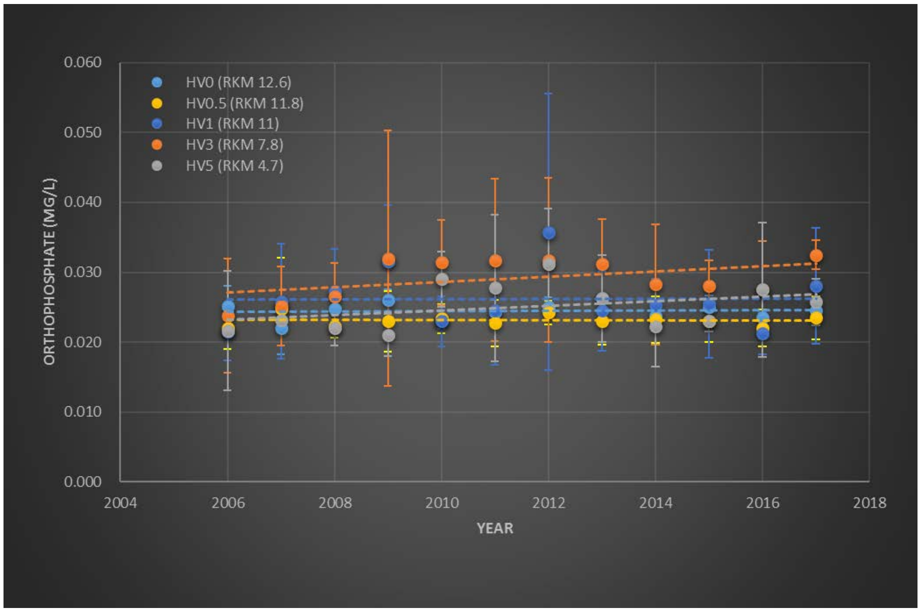


Figure 3-26. Average total phosphorous concentration by station for the period 2006-2017 for the five Coastal Rivers Project P108 fixed water quality monitoring stations.

3.4.4 Soluble Reactive Phosphorous and Orthophosphate

As stated in Section 3.3.4, soluble reactive phosphorous (SRP) and orthophosphate (Ortho-P) are inorganic forms of total phosphorous and are therefore available for uptake phytoplankton and other primary producers. For the period 2006-2017, Ortho-P concentrations have remained relatively consistent (Figure 3-27). Similar to the results for nitrate, relatively large error bars are indicative of the longitudinal concentration gradient from the upper river to the estuary (Figure 3-13). Also, like nitrate, temporal patterns are masked because of this large longitudinal concentration gradient. When each of the five P108 stations are separated into individual components, some interesting patterns emerge (Figure 3-28). Except for the upper two stations HV0 (Rkm 12.6) and HV0.5 (Rkm 11.8), orthophosphate concentrations appear to be decreasing over time.

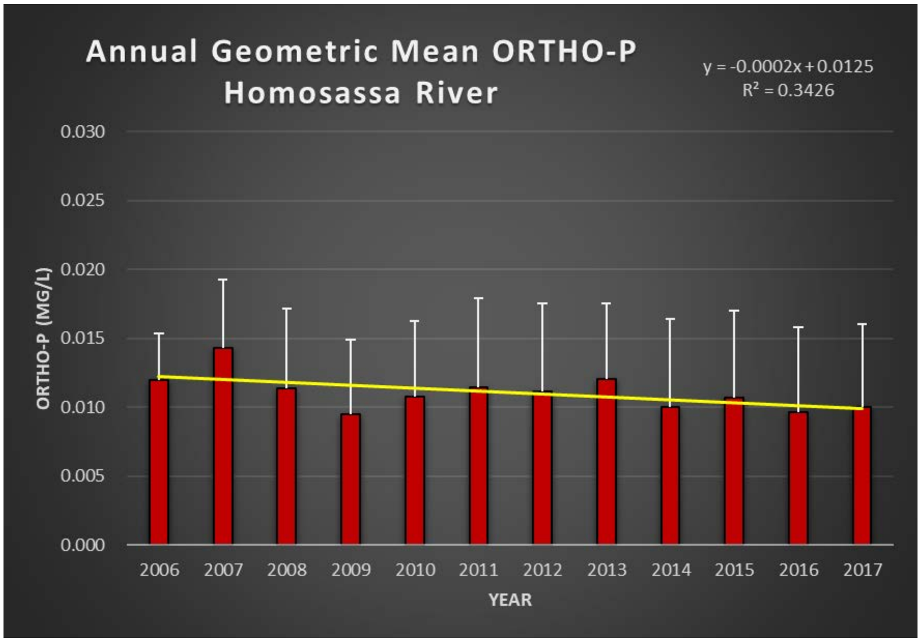


Figure 3-27. River-wide average orthophosphorous concentrations for the period 2006 through 2017. Data are from the five Coastal Rivers Project P108 fixed stations. Error bars represent the standard deviation for each year. Linear regression reveals a slight yet significant decreasing trend in orthophosphorous concentration over the period ($p=0.046$, $R^2=0.34$).

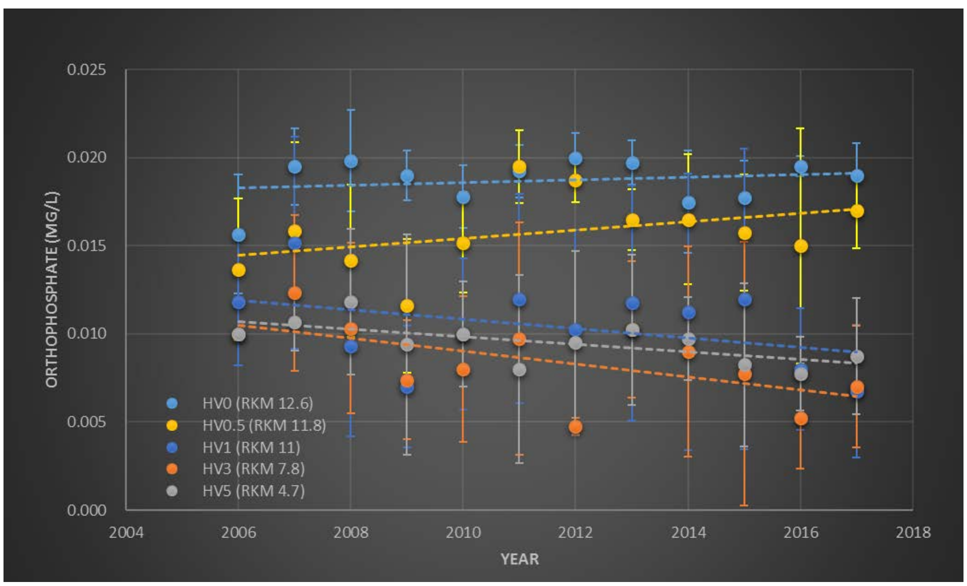


Figure 3-28. Average orthophosphate concentration by station for the period 2006-2017 for the five Coastal Rivers Project P108 fixed water quality monitoring stations.

3.4.5 Chlorophyll

Chlorophyll concentrations for the upper-most Coastal Rivers Project P108 station HV0 (Rkm 12.6) were below the laboratory detection limit of 1.00 µg/L for all samples collected during the period of record 2006 – 2017. Approximately 54% of the samples collected at HV0.5 (Rkm 11.8) and 24% of the samples collected at HV1 (Rkm 11) were below the detection limit. The University of Florida 5 Rivers project did report chlorophyll concentrations below 1.00 µg/L and the time series for three upper river stations show no trend in chlorophyll concentration from 1998 to 2011 (Figure 3-29).

Further downstream, chlorophyll concentrations increase significantly making it easier to detect changes in concentration over time. Between river kilometer 7.6 and 10.7 lies the chlorophyll maximum where concentrations typically remain well above the 1.00µg/L detection limit (Figure 3-15). A time-series plot of Coastal Rivers Project P108 station HV3 (at Rkm 7.8) within this region of maximum chlorophyll reveals an increasing trend in chlorophyll concentration from 2006 – 2017 (Figure 3-30).

There is a site-specific numeric nutrient criteria (NNC) for chlorophyll for the Homosassa River Estuary WBID 1345F which is the section of the lower river from Rkm 0 to Rkm 9 (Figure 3-1). The Coastal Rivers Project P108 stations HV3 and HV5 are contained within the WBID 1345F boundary. The chlorophyll NNC for this WBID is 7.7µg/L, calculated as an annual geometric mean (AGM). When average chlorophyll concentrations for the two active Coastal Rivers Project P108 stations are compared with the chlorophyll NNC, station HV3 (Rkm 7.8) exceeds the chlorophyll NNC for eight of the 12 years of data (Figure 3-31). Conversely station HV5 (Rkm 4.7) remains well below the chlorophyll NNC for the entire period of record (Figure 3-31). Therefore, the location of the chlorophyll maximum relative to the sample location can yield very different criterion exceedance results in this WBID. It is important to note that specific spatial areas, temporal time periods, and statistics are required to determine impairment with this NNC standard. The analyses shown here are not meant to determine impairment but are compared with NNC standard values to establish a frame of reference for the concentrations measured at these stations.

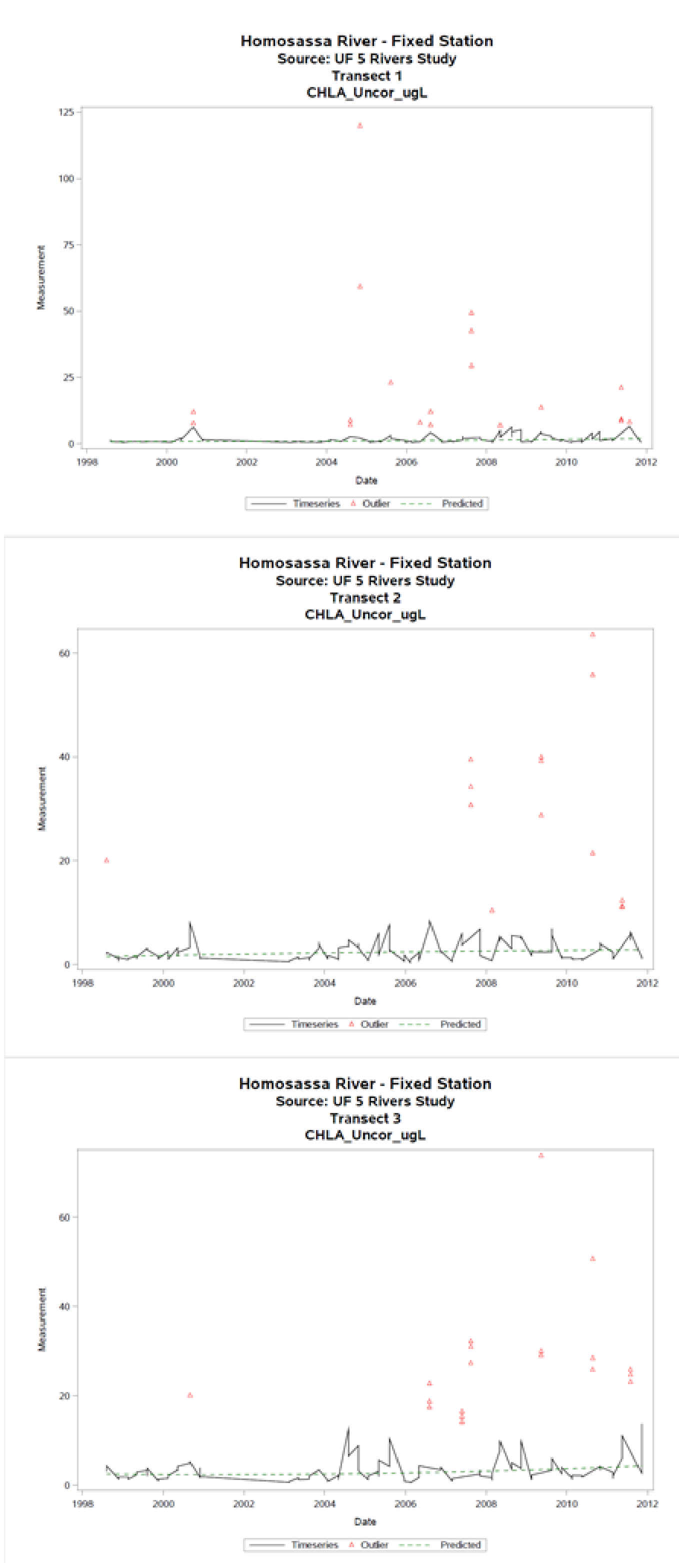


Figure 3-29. Chlorophyll time series for the upper three University of Florida 5 Rivers Project transects for the period 1998 – 2011.

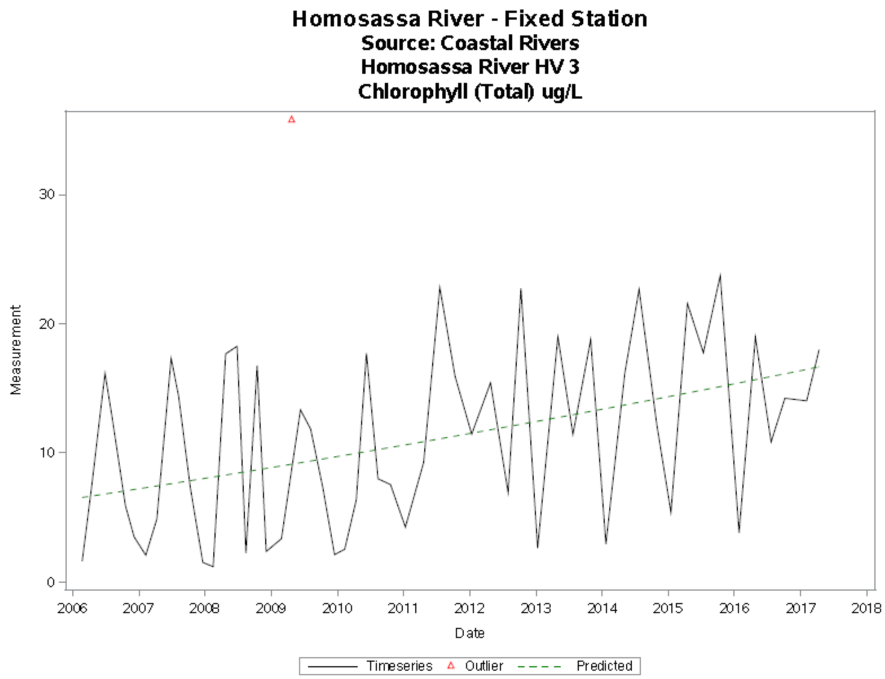


Figure 3-30. Chlorophyll time series for station HV3 approximately 4.8 km downstream of the headsprings (Rkm 7.8) from the active Coastal Rivers Project P108 data collection effort between 2006 and 2017.

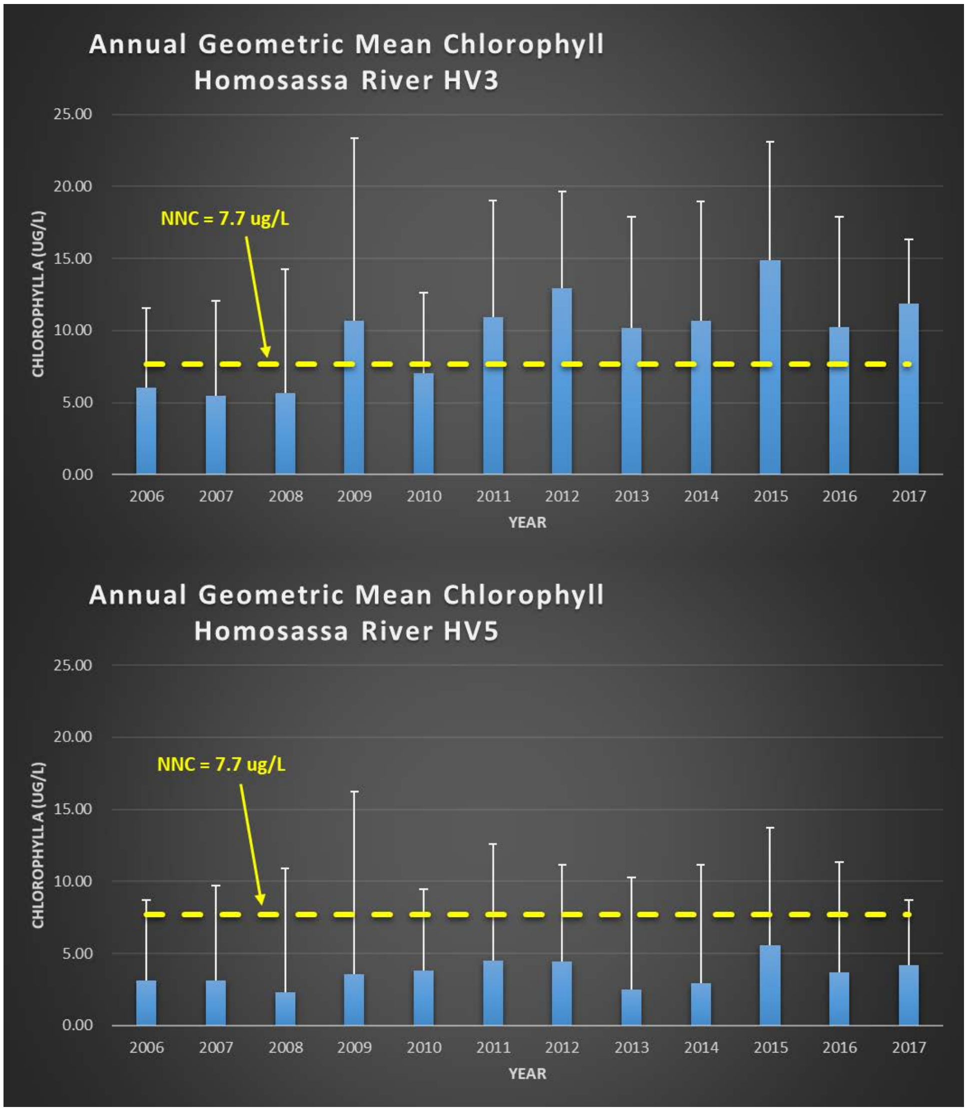


Figure 3-31. Chlorophyll concentration expressed as annual geometric mean for the period 2006 through 2017 for downstream stations HV3 (Rkm 7.8) and HV5 (Rkm 4.7). Error bars represent the standard deviation for each year. Data are from two of the Coastal Rivers Project P108 fixed stations. Yellow dashed line depicts the chlorophyll NNC of 7.7 ug/L for the Homosassa River WBID 1345F. Chlorophyll is compared with the NNC value for comparison only and not for compliance estimation.

3.4.6 Water Clarity

For the Homosassa River, there is considerable interannual variability in water clarity, as measured using a horizontal Secchi disk. By far, the spatial variability in water clarity as explained in section 3.3.6, is much greater than the temporal variability described here. Because of the strong spatial variability, temporal trends were analyzed separately for each of the five Coastal Rivers Project P108 fixed stations. Figure 3-32 shows the annual geometric mean of water clarity for station HV0 near the headsprings. While there appears to be a slight increasing trend in clarity, it is not statistically significant. The remaining four Coastal Rivers Project P108 stations also showed no temporal trends in clarity.

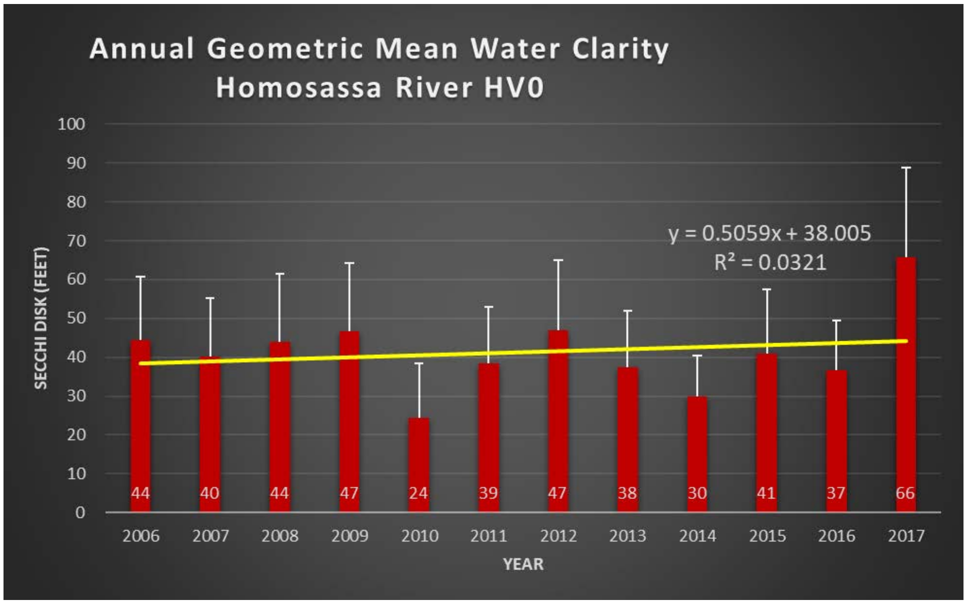


Figure 3-32. Average water clarity for the period 2006 through 2017 expressed as Secchi distance annual geometric mean. Data are from HV0, the upper most station of five Coastal Rivers Project P108 fixed stations. Error bars represent the standard deviation for each year. Linear regression shows no significant trend in clarity over the period ($p=0.992$, $R^2=0.03$).

3.5 Relationship between Flow and Water Quality Constituents

3.5.1 Flow record for water quality analysis

For water quality analyses comparing unimpacted flows to gaged flows which are affected by withdrawal impacts, simulation of an unimpacted record was necessary. For this simulation, withdrawal impacts were gradually increased from zero to present-day levels. This was done because data from the Spring Vents Project P889 extends back to 1993 in the Homosassa River System, when withdrawal impacts were less than they are today. Methods for simulating gradual increases in impacts are detailed below.

Flow data from USGS Homosassa Springs at Homosassa Springs, FL (No. 02310678) and SE Fork Homosassa Spring at Homosassa Springs, FL (No. 02310688) gages were downloaded from the USGS NWIS and combined. Data from USGS Weeki Wachee Well near Weeki Wachee, FL (No. 283201082315601) and USGS Weeki Wachee FLDN REPL Well near Weeki Wachee, FL (No. 2831540823701) were used to predict missing values at the discharge gaging stations and extend records to dates prior to the gaged-streamflow record. Weeki Wachee well data was adjusted for relocation by adding 0.3 ft to the newer (REPL) well levels following methods used for updating regression equations by the USGS (Kevin Grimsley, personal communication). For all dates prior to 1975, withdrawal impact was considered to be zero. For dates from Jan. 1, 1975 to Dec. 31, 2004 the impact was linearly increased daily from 0 to 1.1% because the 2005 withdrawal impact estimated with the NDM was 1.1%. For all dates from Jan. 1, 2005 to Dec. 31, 2009, the impact was linearly increased daily from 1.1% to 1.8% based on the 1.8% withdrawal impact for 2010 estimated with the NDM. For all dates from Jan. 1, 2010 to Dec. 31, 2014, the impact linearly increased daily from 1.8% to 1.9% because the 2015 impact estimated with the NDM was 1.9%. For all dates from Jan. 1, 2015 onward, the impact was considered to be 1.9%. Regardless of time period, missing values were replaced by linear interpolation between adjacent values. These methods are consistent with methods used in the original 2012 minimum flows report for creating a long-term historical flow record and have been updated with new data.

3.5.2 Spring Vents

Linear regression analysis was used to test the hypothesis that concentrations of selected water quality constituents in spring flows were related to system-wide flows (Janicki Environmental, Inc. and WSP, Inc. 2018). Spring Vents Project P889 data used for the analyses included quarterly sampling events generally taken at or near low tide beginning in the early to mid-1990's except for Bluebird, Otter Creek and Southeast Fork Spring vents which were intermittently sampled between 2010 and 2017 (Figure 3-4).

The District has previously developed acceptance criteria for using regression analysis in support of minimum flows evaluations for the Chassahowitzka River (Heyl et al. 2012). These criteria require that regressions must include a) a minimum 10 observations per variable, b) no significant serial correlation and c) an adjusted coefficient of determination (R^2) of at least 0.3. In addition, to be considered for setting minimum flows, regressions would need to be useful for demonstrating increased harm with decreased flows.

There are three general patterns detectable by linear regressions: 1) no relationship – indicating quantity of flows are not associated with concentrations; 2) positive relationships – indicating concentrations increase along with increasing flows; and 3) negative (inverse) relationships – indicating concentrations decrease when flows increase. Harm may be associated with decreased flows when inverse relationships cause increased concentrations of potentially harmful water quality constituents such as nitrogen or phosphorus. Furthermore, these inverse relationships would need to be consistent among water quality monitoring stations and locations throughout the system for them to be used as criteria for setting minimum flows. Regressions that met the District's acceptance criteria are described below. However, there were no spatially consistent inverse relationships with potentially harmful constituents, such as nitrogen or phosphorus, so it was not necessary to consider any of these regressions as criteria for setting minimum flows.

Several water quality parameters collected at the Homosassa 1 spring site were inversely correlated with flow (Figure 3-33). However, none of these constituents at their current concentrations are considered harmful and are naturally occurring constituents of groundwater. It is well known that water that has been in contact with limestone for a relatively short length of time should have low concentrations of calcium and bicarbonate ions and water with a longer period of residency within the flow system should typically have higher concentrations. Similar trends occur in total dissolved solids (TDS), a measure of chemical constituents dissolved in groundwater. In west-central Florida, TDS is mostly influenced by the concentrations of the major ions: calcium, bicarbonate, magnesium, sodium, sulfate and chloride. TDS can be used to estimate the relative residence time of ground water in the aquifer and typically increases as the length of groundwater flow paths increase (Champion and Starks 2001).

Statistically significant relationships with flow were observed for some forms of nitrogen, but these were tenuous, with low numbers of observations and less than 50% of the total variability explained by regressions (Table 3-7). Significant relationships were found for nitrate–nitrite and total nitrogen in the Southeast Fork, both of which were inversely related to flow. However, these relationships are inconsistent with significant positive relationships between total nitrogen and flows in Halls River, as was the relationship between nitrite and flow in Hidden River. Spring vent nitrate, the primary source of nitrogen to the Homosassa River, was not significantly related to flows for Homosassa Spring 1, 2, or 3, or for Pumphouse Spring.

Some of the nitrogen concentrations, especially for nitrite, were very low and near the laboratory detection limits. In addition, the results of the nitrogen regressions were somewhat conflicting based on the direction of the relationships in relation to flow, with positive relationships observed for Hall and Hidden River and negative relationships observed for the Southeast Fork. These findings support those of Upchurch et al. (2008) who evaluated the relationship between nitrates and spring flow in the Suwannee River Water Management District and concluded that minimum flows and levels cannot be used to control nitrate discharging from the springs by promoting high discharge.

Despite the existence of many significant water quality relationships with flow, there was no evidence that decreased flows would cause increased harm associated with the assessed water quality constituents. The positive relationships between major ions (e.g., TDS and its constituents) and flow would only be problematic if they were considered contaminants. However, many of these constituents are trace nutrients that are valuable for biological productivity. In addition, for forms of nitrogen that decreased with flow, the total mass of the constituent may be increasing (Heyl et al. 2012), and that total mass may be a more important driver of response of biota in the receiving water bodies. Future research should consider the utility of developing nitrate loadings from the head springs. In summary, there is no evidence that relationships between any assessed water quality constituents and decreased flow would result in significant harm to the receiving waters of the Homosassa River System.

As shown in Figure 3-22, nitrate levels have been increasing over time in water discharged from spring vents. This spring discharge is the source of nitrates to the spring pools and river system. Therefore, increasing flows will increase the total amount of nitrogen (loading) fed into the system. The intuitive wisdom that increasing flows will decrease concentrations does not apply to this system where spring flows are the source of nitrates.

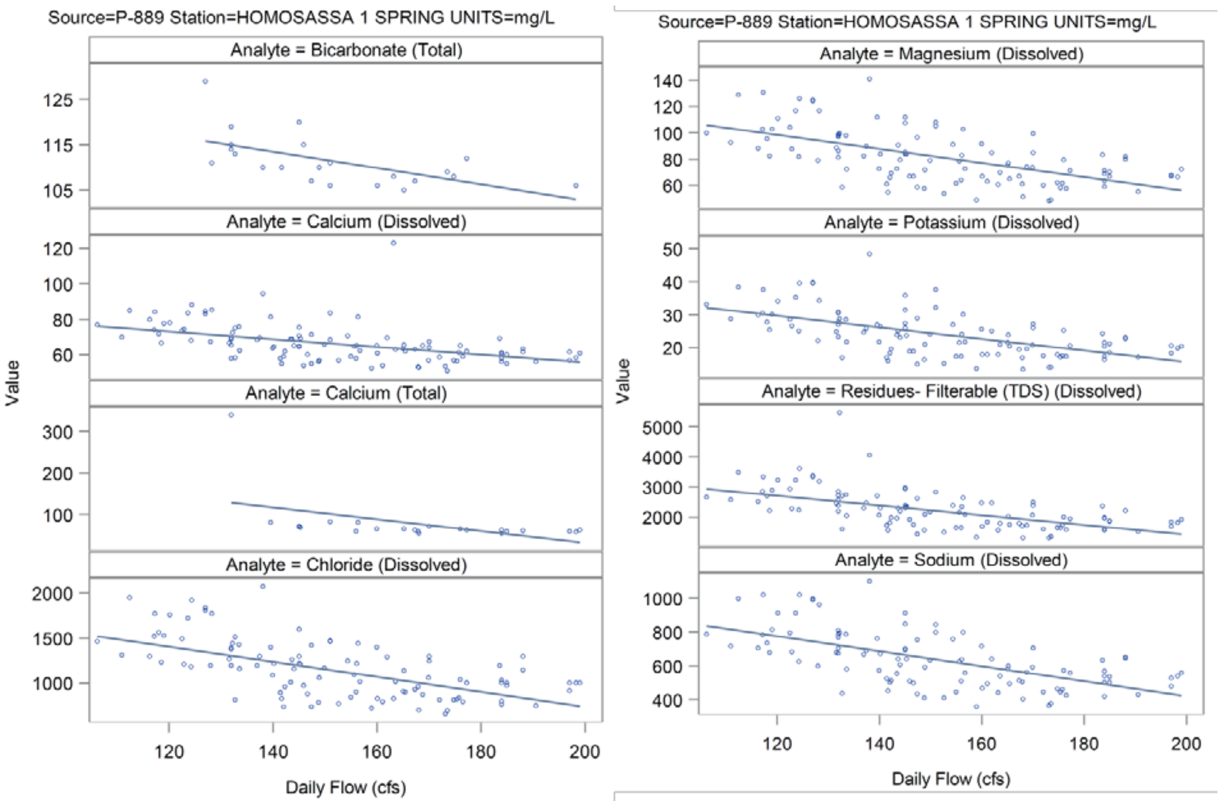


Figure 3-33. Regression relationships between a select group of water quality constituents from Spring Vents Project P889 data and flows in the Homosassa River System. Reproduced from Janicki Environmental, Inc. and WSP, Inc. (2018).

Table 3-7. Significant regression results between nitrogen and flows in Springs in the Homosassa complex.

Site Name	Parameter	Units	Intercept	Slope	DF	R^2	P Value
SE Fork	Nitrite + Nitrate (N) (Total)	mg/L	0.9283	-0.0017	19	0.31	0.0090
SE Fork	Nitrogen - Total (Total)	mg/L	0.9037	-0.0013	19	0.38	0.0029
Halls River	Nitrogen - Total (Total)	mg/L	0.0747	0.0020	23	0.32	0.0033
Hidden River	Nitrite (N) (Total)	mg/L	-0.0048	0.0001	39	0.35	0.0001

3.5.3 River Mainstem

It has been suggested that residence time may be linked to algal growth, and that increasing flows will reduce residence times and therefore reduce harmful algal growth. Residence time is not one quantity, but can be measured in various ways, one of which is water age, which is the time it takes for a molecule of water to travel a distance from the headsprings downstream. At any given time and under any flow regime, water age increases with distance downstream (Figure 3-34). Increasing 3-day average flows from 122 to 196 cfs consistently lowers water age throughout the system. However, rather than focusing on residence time as an intermediary between flows and algal growth, the following analyses focus directly on the abundance of phytoplankton as estimated by chlorophyll concentration. This is because the environmental characteristic of interest to most users of the river is water clarity, which is partly driven by chlorophyll via absorption of electromagnetic energy primarily in the blue and red wavelengths. As explained in section 3.3.6, chlorophyll is only one of two major attenuators of light in the Homosassa River, the other being TSS. Therefore, caution should be taken when attempting to assign cause and effect relationships between chlorophyll and clarity, and between clarity and flow. Janicki Environmental, Inc. and WSP, Inc. (2018) found no significant correlation between Secchi disk and flow for any of the stations where Secchi disk readings were made.

Regardless of the relationship between chlorophyll and clarity, chlorophyll concentration is a widely accepted indicator of eutrophication and therefore an important ecological parameter to monitor. In an initial screening of data, non-linear relationships were found between flows and chlorophyll for several of the University of Florida 5 Rivers Project transect sites in the upper portion of the mainstem of the river (Janicki Environmental, Inc. and WSP, Inc. 2018). The University of Florida 5 Rivers Project data was selected for these analyses because its sampling design was spatially intensive with 20 transect locations within 14 kilometers of the river, and because of the relatively long period of record (Figure 3-35). The statistical approach used identifies risk of exceeding a threshold chlorophyll value and associates that risk with rates of flow.

The analysis we used identifies a threshold value and calculates risk of individual samples exceeding that value. To perform this analysis a threshold must be selected, and that threshold should be relevant to the system being studied. District staff identified a value of 7.7 µg/L as the most relevant threshold to use. Note, it is critical to distinguish between our use of this value as a threshold for analysis and its prescribed use as a criterion for determining impairment within the Estuary-Specific Numeric Interpretations of the Narrative Nutrient Criterion (NNC) (Table 3-1). This value, taken as the NNC, is applicable only within WBID 1345F (see Figure 3-1) and as an annual geometric mean value according to Rule 62-302.532 F.A.C. Contributing to our decision to use this 7.7 µg/L value, associated with the downstream 1345F WBID, is that the upstream WBID (1345) does not have a chlorophyll NNC value. We used this same value of 7.7 µg/L, but for a different purpose than determination of impairment of the NNC. Thus, an instance of a single exceedance of this threshold, or an increased risk of this exceedance across several repeated samples both inside and outside the WBID boundary cannot and should not be interpreted in the context of impairment of the NNC.

To test the hypothesis that exceedances of the 7.7 µg/L chlorophyll threshold were related to spring flow, a generalized linear mixed effects model was applied for predicting the probability of an exceedance of the 7.7 µg/L chlorophyll threshold chlorophyll concentration (a binomial response; either the threshold is exceeded, or it is not) as a function of flow.

Fifteen flow reduction scenarios were developed for use with the generalized linear mixed effects model. The scenarios included 1% to 15% reductions in flow from the unimpacted flow record for the Homosassa River, in 1% increments. The period from 1998 through 2017 was used for the scenarios because this period approximates the full, combined period of record for the Homosassa Spring at Homosassa Springs, FL gage (No. 02310678) and SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688). Chlorophyll responses were predicted for the entire system, while comparisons between the flow reduction scenarios and the unimpacted (no flow reduction) flow scenario were limited to the area between University of Florida 5 Rivers Project sites 1 and 11 (i.e., upstream of Rkm 7.2) because this portion of the system is most likely to be directly influenced by spring flows (Figure 3-35).

Model-predictions for the flow reduction scenarios were evaluated using two forms: Best Linear Unbiased Predictions (BLUPs) and Best Linear Unbiased Estimates (BLUEs). BLUPs more accurately represent differences among sites within the focus area, while BLUEs generate artificially smooth transitions from one site to the next.

Results show that that both BLUPs and BLUEs predict increased risks of exceedance of the 7.7 µg/L chlorophyll threshold with increased flow reductions (Figure 3-36). BLUEs predict more sensitive responses to all flow reductions. The interpretation of these results for minimum flows determination is discussed further in Chapter 7.

To date, the District has not used phytoplankton distributions as the principal determinant for establishing minimum flows. Chlorophyll concentrations have, however, been used to support establishment of a low-flow threshold for the Lower Alafia River (Flannery et al. 2008). Moreover, chlorophyll concentrations were recently used by the South Florida Water Management District in comparison to state water quality standards as a line of evidence supporting derivation of a revised minimum flow for the Caloosahatchee River estuary (South Florida Water Management District 2018). Based on these examples, there are alternative modeling approaches that consider actual chlorophyll concentrations (rather than risks of exceedance) as a response variable. However, there are currently no applicable standards for identifying “significant harm” associated with increased chlorophyll concentrations.

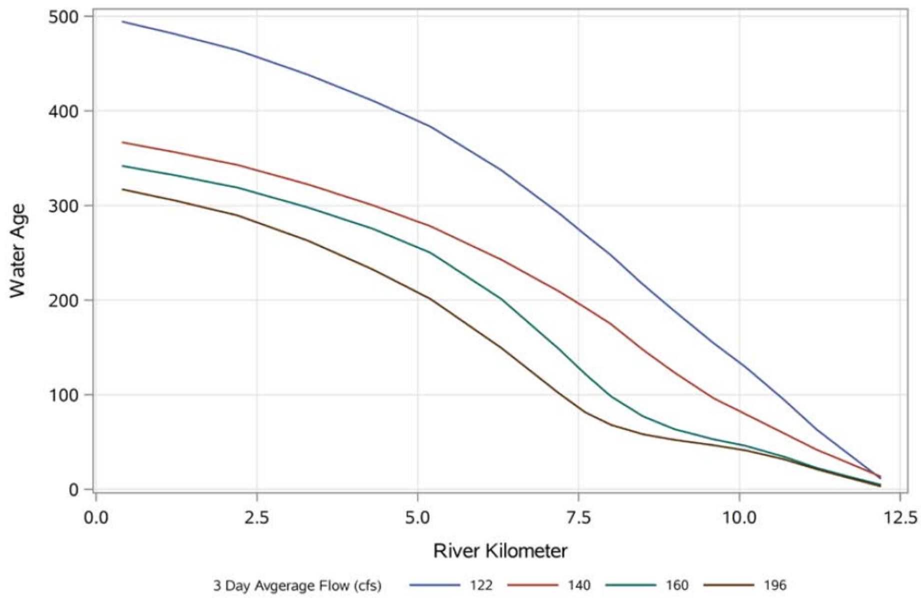


Figure 3-34. Water age as a measure of “residence time” varies with average flow and river kilometer.

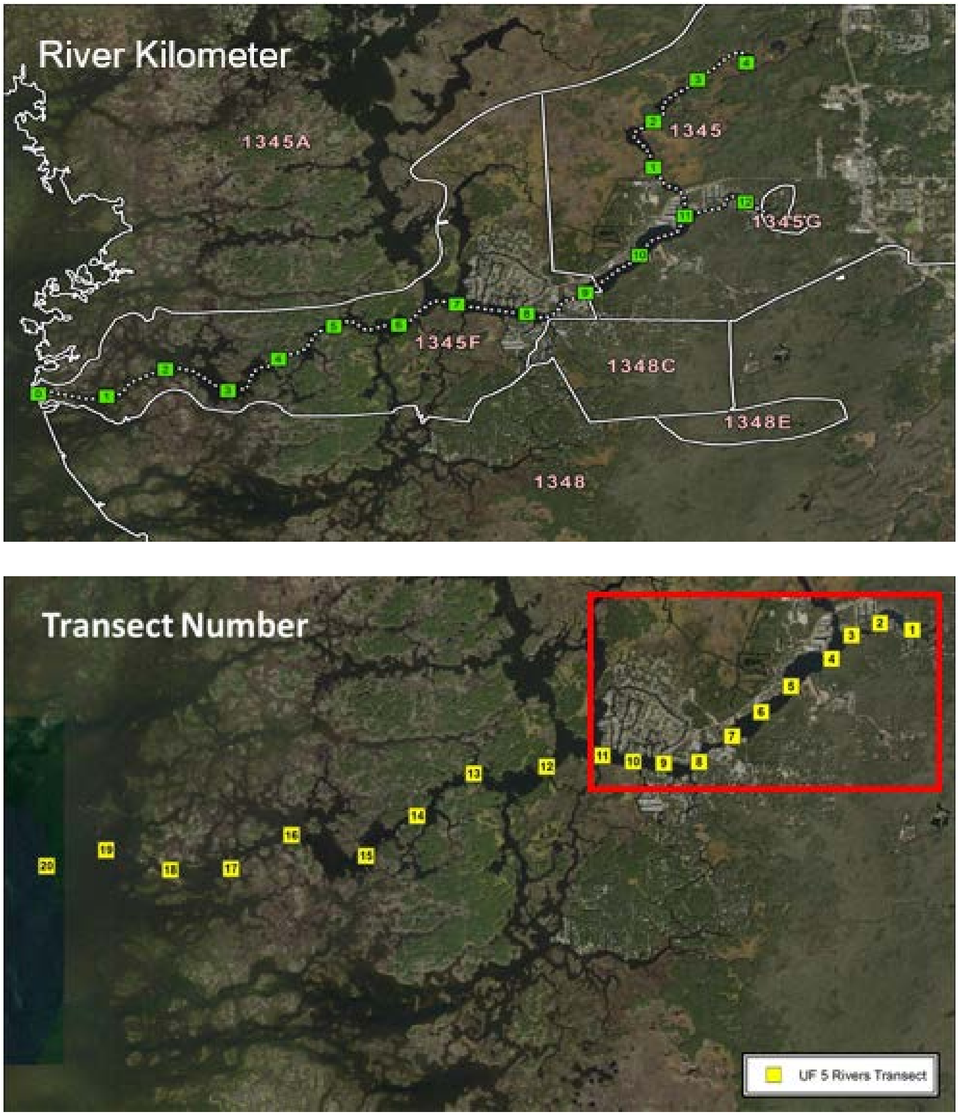


Figure 3-35. River kilometer, WBID boundaries (upper panel), and University of Florida 5 Rivers Project transect numbering system (lower panel) for the Homosassa River. Red box in the lower panel identifies the area used for relative comparisons of chlorophyll concentrations between d flow-reduction and unimpacted (no flow reduction) scenarios.

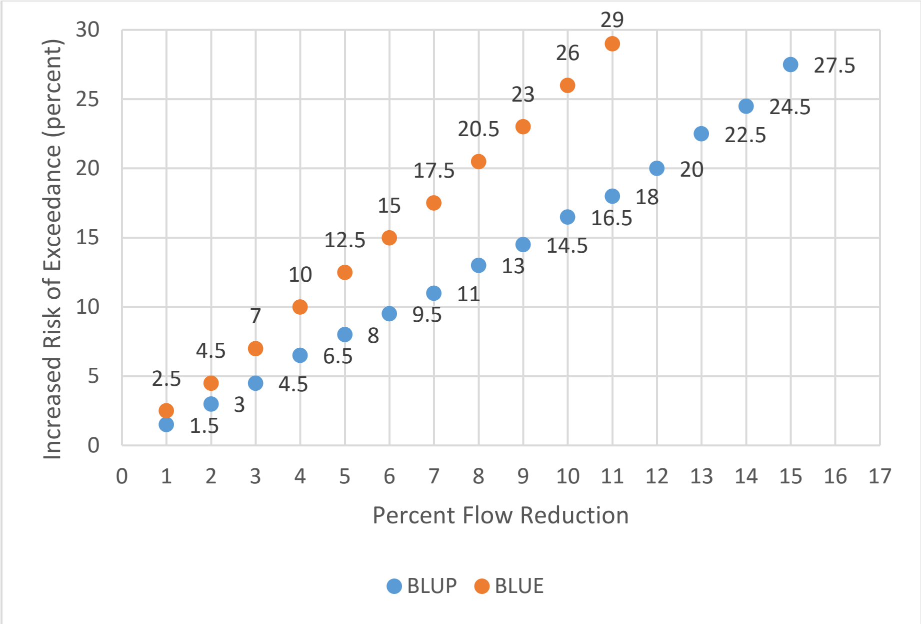


Figure 3-36. Increased risk of exceeding the 7.7 µg/L chlorophyll threshold with flow reductions as predicted by BLUPs and BLUEs. Increased risks are compared between flow reduction scenarios and the unimpacted flow scenario.

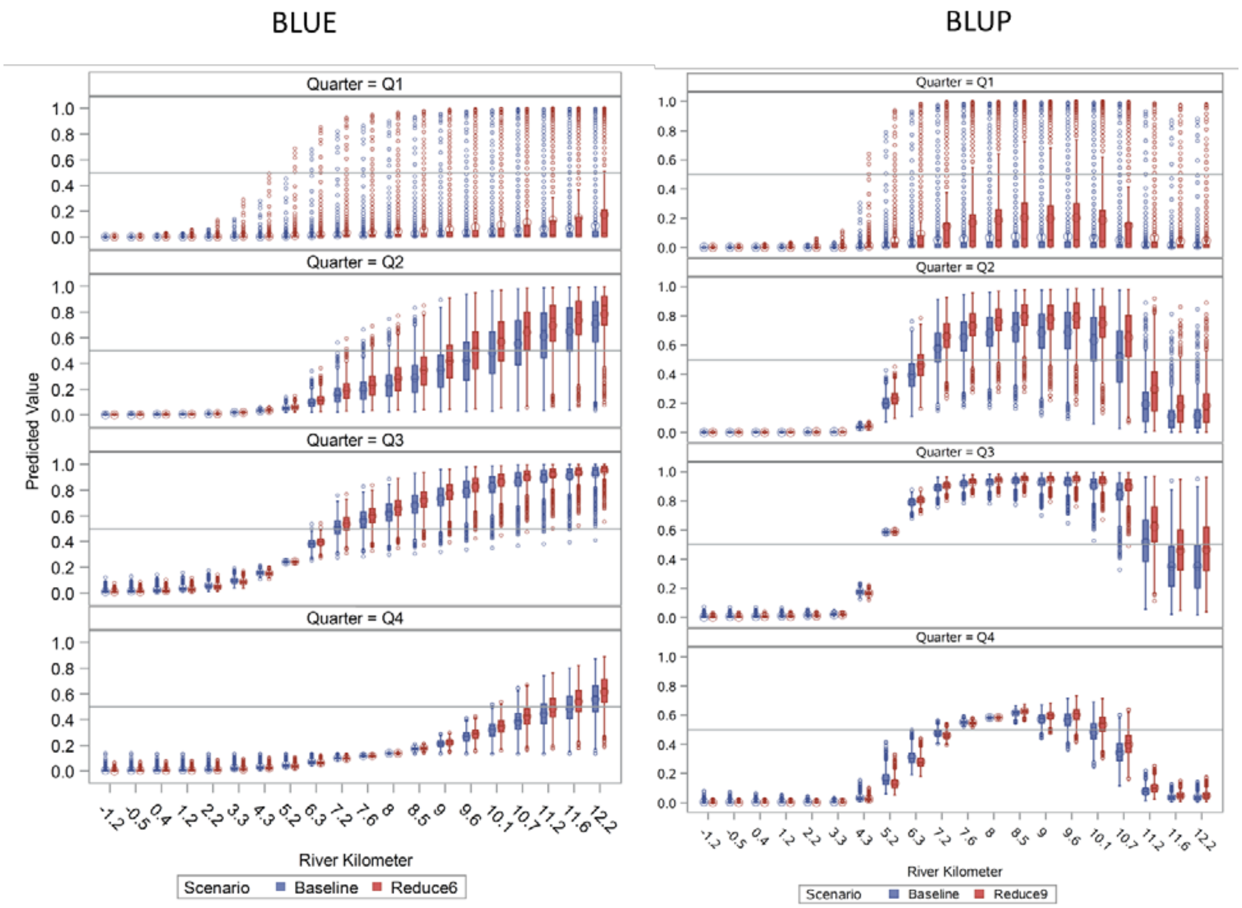


Figure 3-37. Results of flow reduction scenarios on increase in relative risk of exceeding a chlorophyll threshold of 7.7 µg/L associated with a numeric nutrient criterion established for a lower portion of the river (i.e., downstream of Rkm 9) for sites in the Homosassa River System. Numbers above bars represent the relative risk compared to the unimpacted (no flow reduction scenario) for each scenario.

3.5.4 Estuary

Janicki Environmental, Inc. and WSP, Inc. (2018) also developed and assessed regressions between water quality constituents and flow at estuary sites beyond the mouth of the river (Rkm 0) using the same statistical methods as for spring vent sites (see Section 3.5.2). Estuary sites analyzed include four COAST Project P529 sampling stations and two transects from the previously completed University of Florida 5 Rivers Project (Figure 3-38).

Salinity was the principal water quality constituent affected by spring flows (Figure 3-39). Salinity in the estuary beyond the mouth of the river decreases with increasing flows. Similar results were reported by Yobbi and Knochenmus (1989), who found salinity isohalines moved from the river out to the Gulf of Mexico. The 25-ppt isohaline moved from six miles outside the mouth to about

1 mile upstream of the mouth, and the 18-ppt salinity isohaline moved from between 2 miles outside the river mouth to about 4 miles upstream of the mouth.

Given that the estuarine area examined in this current analysis is so far removed from springs flows and is affected by direct rainfall, surface flows from coastal zone runoff, and wetland storage, there is little utility in directly using these regressions to support the establishment of minimum flows for the Homosassa River System. Furthermore, the hydrodynamic model described in Chapter 6 is a much more precise and accurate tool for predicting salinity changes associated with flow reductions.

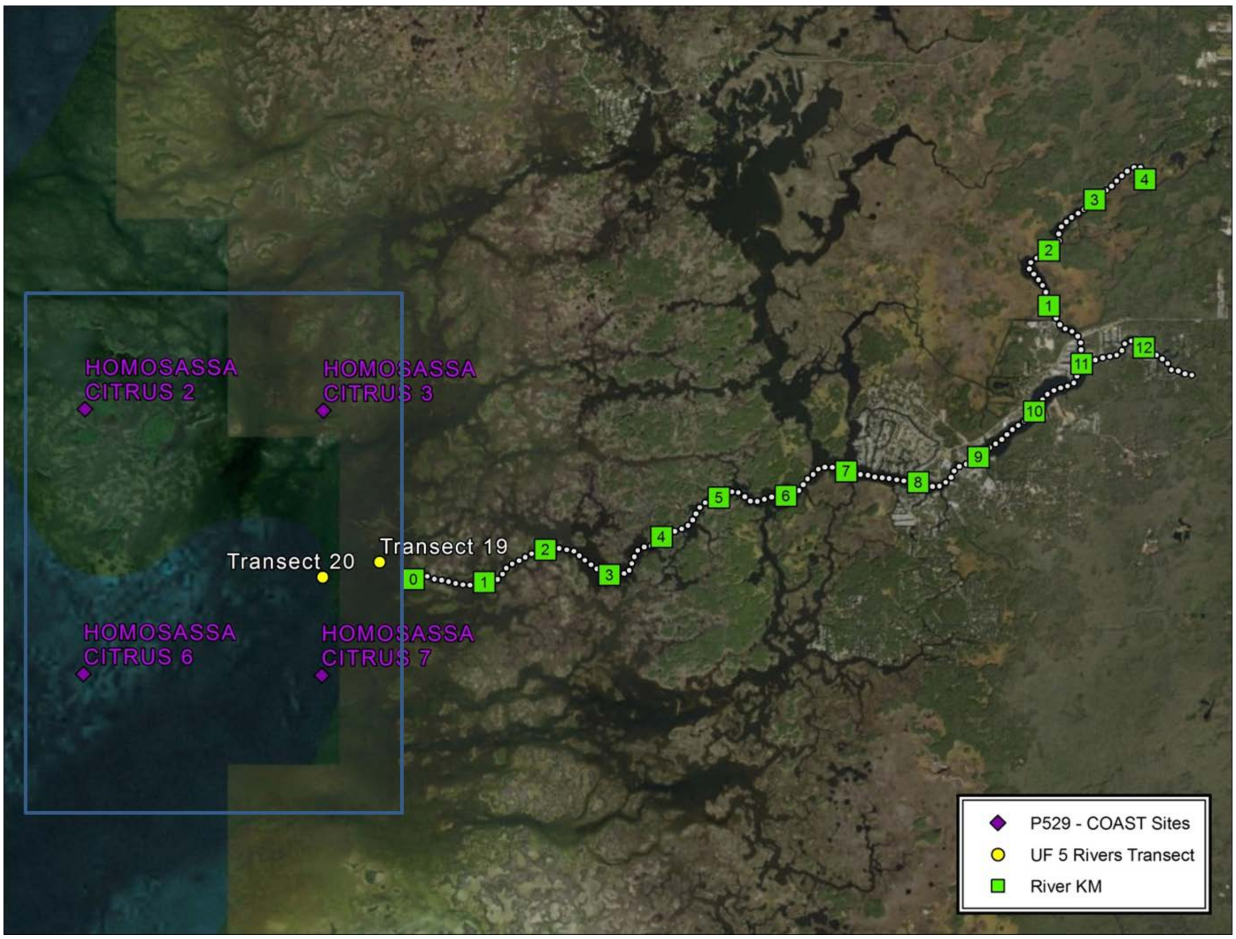


Figure 3-38. Sampling areas in the Homosassa River estuary outside of the Homosassa River System hydrodynamic model domain (highlighted by blue rectangle).

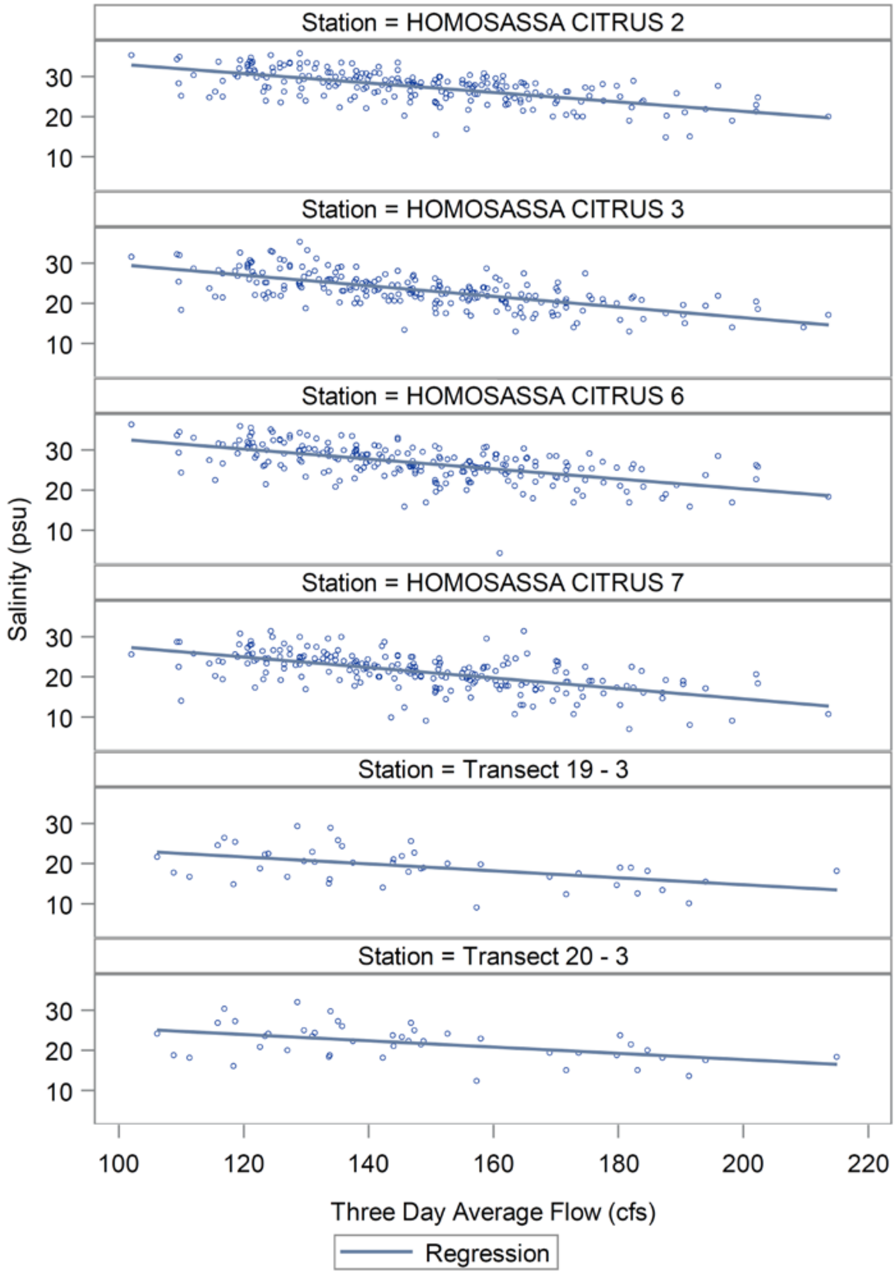


Figure 3-39. Regression relationships between salinity at the Homosassa River estuary stations and 3-day average flow. Reproduced from Janicki Environmental, Inc. and WSP Inc. (2018).

CHAPTER 4 - BIOLOGICAL STATUS AND TRENDS EVALUATION FOR THE HOMOSASSA RIVER SYSTEM

Plants and animals in the Homosassa River System have historically formed diverse communities structured by the estuarine gradient from freshwater headsprings to the saltwater mouth of Homosassa Bay. Because salinity and temperature are responsible for structuring communities of fish, invertebrates and plants throughout the system, it is important to have a baseline knowledge of these communities in order to effectively detect changes in these communities that may be caused by reduced flows or decreased water quality. Since the original minimum flows evaluation and rulemaking in 2013, the District has continued monitoring vegetation, fish, and other biological aspects of this system as part of our adaptive management strategy for dealing with uncertainty in this inherently complex system.

4.1 Vegetation

4.1.1 Natural Communities and Land Cover Types

The Homosassa River is imbedded in a variety of natural vegetative communities, with those along the shoreline more strongly affected by the salinity and hydrologic regimes of the river and its springs. Wolfe (1990) focused on summarizing information about communities found within the Florida Springs Coast region, profiling terrestrial, freshwater, estuarine, and coastal habitats. The Florida Natural Areas Inventory recognizes a hierarchical classification of 81 natural communities based on a combination of vegetation, landscape position, and hydrology (Florida Natural Areas Inventory 2010). Among the important considerations for landscape position are proximity to streams, floodplains, and topology of low-lying areas.

The Florida Land Use, Cover, and Forms Classification System (FLUCCS) and the Florida Cooperative Land Cover (CLC) map are two methods of classifying land cover in Florida. The CLC was developed using and expanding upon FLUCCS types and includes a crosswalk table with FLUCCS codes. FLUCCS is designed to serve as a uniform land classification system for a wide variety of users (FDEP 1999). The Florida Cooperative Land Cover Map (CLC) is a partnership between the Florida Fish and Wildlife Conservation Commission (FWC) and Florida Natural Areas Inventory (Florida Natural Areas Inventory) to develop ecologically-based statewide land cover from existing sources (including FLUCCS) and expert review of aerial photography (Florida Natural Areas Inventory 2016). The CLC was originally funded by the Florida's State Wildlife Grants program in support of The Florida State Wildlife Action Plan which identified improved habitat mapping as a priority data gap. The CLC follows the Florida Land Cover Classification System (Kawula 2014).

FLUCCS cover surrounding the Homosassa River System is dominated by 7 natural cover types, two of which are water – Bays and Estuaries and Gulf of Mexico, and 5 of which are land – Freshwater Marshes, Hardwood Conifer Mixed, Saltwater Marshes, Stream and Lake Swamps (bottomland), and Wetland Forested Mixed (Figure 4-1). CLC cover is dominated by 8 cover types including two water types – Estuarine and Marine, and 6 terrestrial – Hydric Hammock, Mesic Hammock, Mixed Hardwood-Coniferous, Mixed Wetland Hardwoods, Other Wetland Forested

Mixed, and Salt Marsh (Figure 4-2). The FLUCCS Gulf of Mexico coverage is nearly identical to CLC Marine area, while the FLUCCS Bays and Estuaries is nearly identical to CLC Estuarine types. In addition to the named terrestrial cover types there are various other natural land types that make up a small portion of the remaining area and are therefore not describe here. There are also a variety of developed residential and other land use types in the communities of Homosassa and Homosassa Springs.

The FLUCCS identifies Freshwater Marshes in locations surrounding the Halls River where the CLC identifies Salt Marsh and Other Wetland Forested Mixed (Figure 4-1, Figure 4-2). Likewise, FLUCCS Saltwater Marshes correspond to CLC Salt Marsh except where CLC Salt Marsh extends into areas identified by FLUCCS as Freshwater Marsh. FLUCCS Freshwater Marshes are characterized by a predominance of one or more of several grass species including: sawgrass (*Cladium jamaicense*), cattail (*Typha spp.*), cordgrass (*Spartina bakeri*), and bulrush (*Scirpus spp.*) (FDEP 1999). FLUCCS Salt Marshes are defined by the predominance of one or more of: saltmarsh cordgrass (*Spartina spp.*), needlerush (*Juncus roemerianus*), seashore saltgrass (*Distichlis spicata*), saltwort (*Batis maritima*), glassworts (*Salicornia spp.*), and seaside daisy (*Borrichia frutescens).* CLC Salt Marsh is defined as treeless estuarine wetland with a dense herb layer on muck/sand/or limestone substrate, which is inundated with saltwater by daily tides, and includes the species named in the FLUCCS type of the same name.

The FLUCCS Hardwood Conifer Mixed area largely corresponds to the CLC Mixed Hardwood-Coniferous coverage, but there is one region where FLUCCS Hardwood Conifer Mixed overlays CLC Mesic Hammock in the area between the Hidden River and Otter Creek in addition to a few other small, scattered areas (Figure 4-1, Figure 4-2). FLUCCS Hardwood Conifer Mixed and CLC Mixed Hardwood-Coniferous are cross walked together by the CLC (Kuwala 2014), and this habitat type is the only upland type identified here. These uplands include all forested areas in which neither upland conifers nor hardwoods achieve a 66 percent crown canopy dominance.

FLUCCS Stream and Lake Swamps (Bottomland) covers three CLC natural areas: Hydric Hammock, Mesic Hammock, and Mixed Wetland Hardwoods (Figure 4-1, Figure 4-2). FLUCCS Bottomland is usually found on but not restricted to river, creek and lake flood plain or overflow areas. This category has a wide variety of predominantly hardwood species of which Homosassa representatives include red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), willows (*Salix spp*.), water hickory (*Carya aquatica*), bays (*Magnolia virginiana, Persea palustris, Persea borbonia*), and water ash (*Fraxinus caroliniana*). Hydric Hammock (CLC) is a lowland with sand/clay/organic soil over limestone or with high shell content found primarily in the eastern Panhandle and central peninsula of the state and is home to swamp laurel oak (*Quercus laurifolia*), live oak (*Q. virginiana*), cabbage palm (*Sabal palmetto*), and red cedar (*Juniperus virginiana*). Mesic Hammock is flatland with sand/organic soil, located primarily in the central peninsula, and includes live oak (*Q. virginiana*), cabbage palm (*S. palmetto*), southern magnolia (*M. virginiana*), and saw palmetto (*Serenoa repens*). Mixed Wetland Hardwoods (CLC) includes Wetland hardwood communities which are composed of a large variety of hardwood species tolerant of hydric conditions yet exhibit an ill-defined mixture of species and correspond directly to a FLUCCS type of the same name.

FLUCCS Wetland Forested Mixed corresponds (with a few small exceptions) to CLC Other Wetland Forested Mixed (Figure 4-1, Figure 4-2). Wetland Forested Mixed and CLC Other

Wetland Forested Mixed are both defined as mixed wetlands forest communities in which neither hardwoods nor conifers achieve a 66 percent dominance of the crown canopy composition. The Wetland Forested Mixed areas within the Homosassa River System fit the description of the Coastal Hydric Hammock which is described as “strips of hammock immediately bordering salt marsh or other coastal communities” (Florida Natural Areas Inventory 2010). The CLC has a Coastal Hydric Hammock type, yet there are no mapped areas identified as this type between the Withlacoochee River and the mouth of the Peace River, despite their common coverage in this area.

Coastal Hydric Hammocks are found where elevation increases on the landward edge of the marsh or in isolated pockets where the vegetation transitions through halophytic marsh and scrub into hammock communities dominated by cabbage palm (*Sabal palmetto*), southern red cedar (*Juniperus virginiana*), and live oak (*Quercus virginiana*) (Vince et al. 1989, Williams et al. 1999).

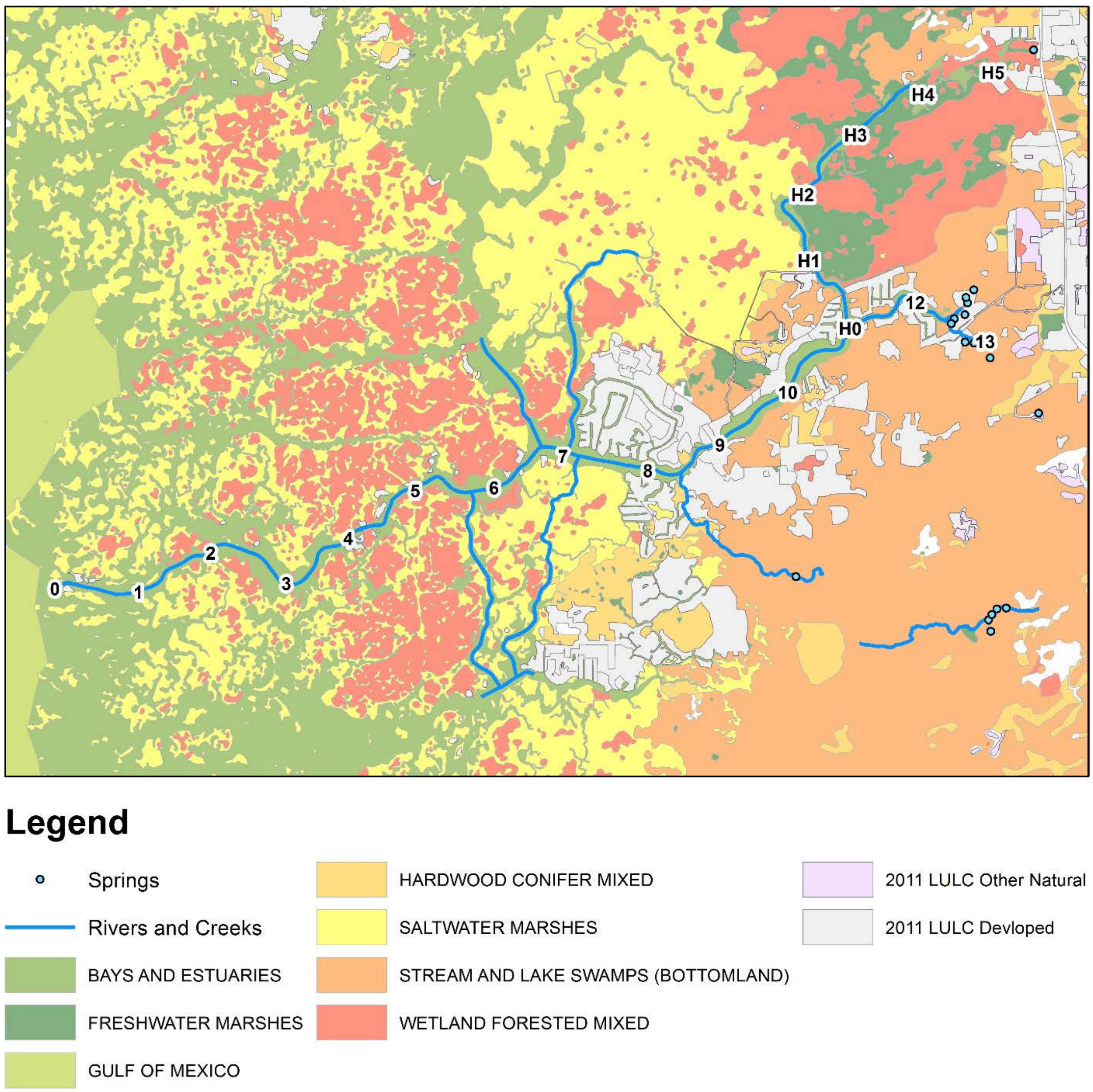


Figure 4-1. Vegetative cover types in the vicinity of the Homosassa River System by FLUCCS code.

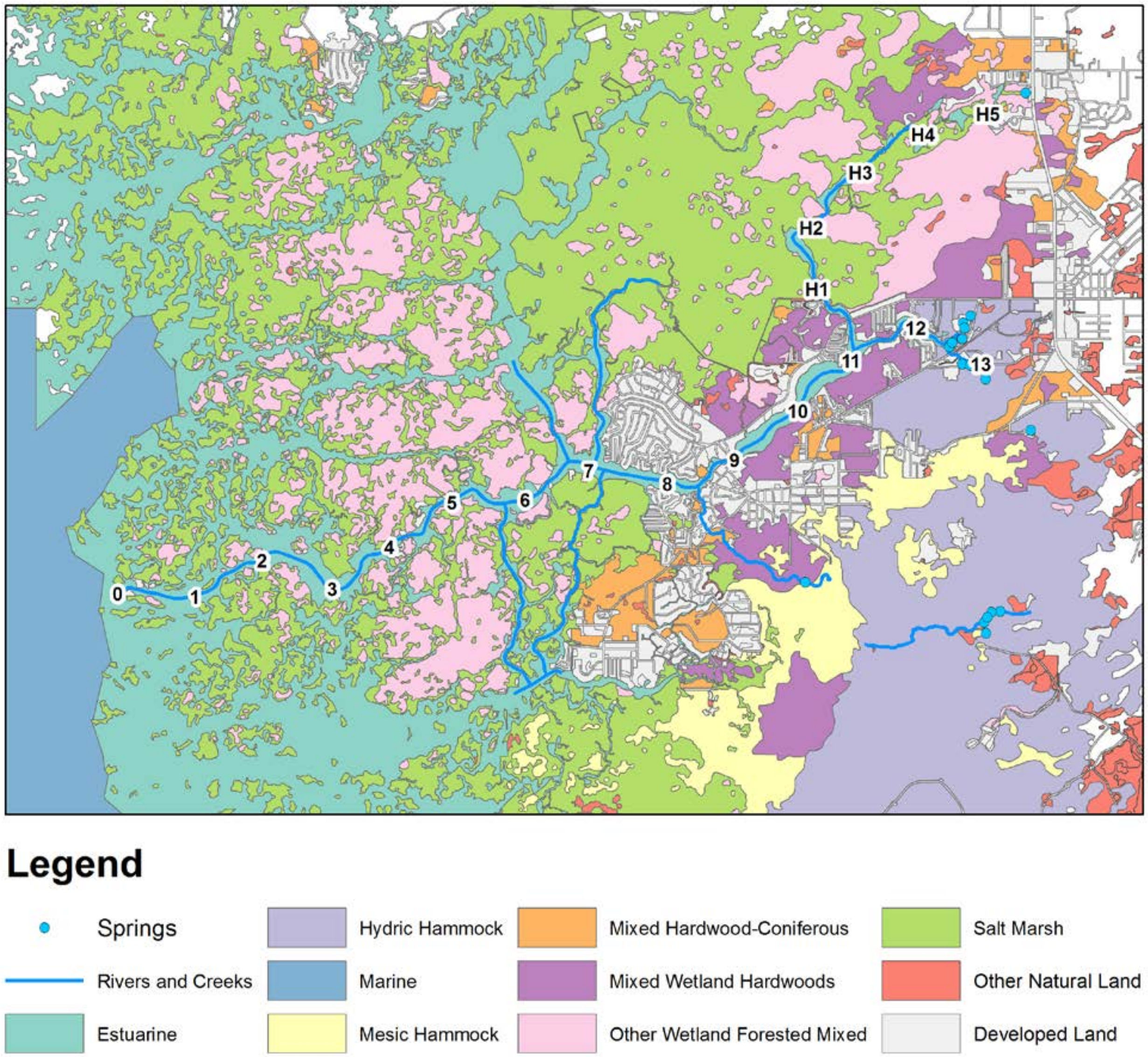


Figure 4-2. Natural plant communities in the vicinity of the Homosassa River System identified by Florida Cooperative Land Cover map (Florida Natural Areas Inventory 2016). Descriptions of natural communities are found in the Guide to the Natural Communities of Florida (Florida Natural Areas Inventory 2010).

4.1.2 Shoreline Vegetation Mapping

Surveys of the vegetation present in the Homosassa River System provide information about the status and trends in species distribution and abundance as well as the factors that drive changes over time. The consultant PBS&J (2009) identified and mapped species of submerged aquatic vegetation (SAV) and shoreline vegetation. Results of this effort are summarized in a report dated 2009 and include a geodatabase with mapped shoreline and submerged vegetation. Plants are categorized by tolerance to salinity, and species distributions are compared to salinity isohalines. Comparisons are made to past District SAV mapping and efforts by Frazer et al. (2001, 2006), which were also funded by the District. The consultant Water and Air Research (2018a [Appendix 9]) was tasked with mapping shoreline features of the Chassahowitzka and Homosassa River systems. Methods used were consistent between these two systems, and incorporated elements of previous mapping efforts, including the previous Homosassa River shoreline mapping. Mapping of shoreline vegetation was limited to the first five feet of the shoreline and divided into 30 foot-long segments. When compiling vegetation data for a segment, each distinct species was classified as dominant, co-dominant or present to characterize relative abundance. Dominant species were defined as generally covering at least 40 percent or more of a segment with no other species having higher than 25 percent cover. Additionally, if only one species was present in a segment, that species was classified as dominant regardless of abundance. Co-dominant species were defined as multiple (typically two) species within a segment having similar cover of at least 25 percent or higher with no other species in higher abundance. Present species were defined as having at least 1 percent cover and not designated as dominant or co-dominant.

Plant species distributions along the shoreline of the Homosassa River System are sensitive to changes in salinity. Salinity exhibits a natural gradient from the headsprings to the Gulf of Mexico (Figure 4-3). The location of the USGS Homosassa River at Homosassa, FL gage (No. 02310700), with an average daily salinity range of 2.7 to 6.4, is at the downstream extent of the Mixed Wetland Hardwoods community. Salt marshes and coastal hydric hammocks are located in areas near higher salinity waters. Hydric hammocks are located near the freshest waters of the SE Fork.

Many freshwater forest trees including red maple (*Acer rubrum*), ash (*Fraxinus sp*.), sweetbay (*Magnolia virginiana*), southern wax myrtle (*Morella cerifera*), swamp bay (*Persea palustris*), and swamp laurel oak (*Quercus laurifolia*) are found only above Rkm 8 (Figure 4-4). These trees are indicative of freshwater forested wetlands and correspond to CLC mapped areas of mixed wetland hardwoods, hydric hammock, and other wetland forested mixed (Florida Natural Areas Inventory 2016, Kawula 2014). The downstream limit of these trees roughly corresponds to the location of the USGS Homosassa River at Homosassa, FL gage (No. 02310700) with an average daily maximum salinity ranging from 2.7 to 6.4 (Figure 4-3). In a review of seven coastal Florida rivers, Clewell et al. (2002) ranked *Morella cerifera*, *Persea palustris*, *Magnolia virginiana, and Fraxinus caroliniana* as 16, 19, 20 and 24 out of 24 common plants in terms of salt tolerance (*Acer rubrum* and *Quercus laurifolia* were not ranked). Therefore, these plants are indicative of a freshwater shoreline. The spatial range of the distributions of these freshwater species does not appear to have expanded or contracted from 2008 to 2018, although the 2018 survey shows a more comprehensive coverage for some species (Water and Air Research, Inc. 2018a). Wetland Solutions, Inc. (2010 and appendices) characterized the shoreline vegetation along the main springs pool and run and noted many of the same species identified by Water and Air Research, Inc. (2018a).

Saltwater tolerant plants limited to downstream reaches of the Homosassa River System include black mangrove (*Avicennia germinans)*, buttonwood (*Conocarpus erectus*), and white mangrove (*Laguncularia racemosa*) (Figure 4-5). There are no mangrove forests identified at the community level, and these plants are limited to areas identified as saltmarsh and other wetland forested mixed. It is common for mangroves to grow along the fringes of saltmarshes (Florida Natural Areas Inventory 2010). The 2018 survey covered a broader geographical area and detected these halophytic plants in Battle, Petty, and Mason Creek outside the survey area for the 2008 study. White mangroves were not detected in 2008 but were found in conjunction with other mangroves and buttonwoods in 2018.

The distribution of red mangroves (*Rhizophora mangle*) appears to have expanded upstream. In 2008, these mangroves were limited to areas below Rkm 7, while in 2018 they were found further upstream to Rkm 11 (Figure 4-6). This may represent a range expansion and may also be a consequence of more thorough sampling effort. Red mangroves also appear to be much more dominant from Rkm 0 to Rkm 2 in 2018 compared with 2008. Expansion of mangroves northward in Florida has been linked to global climate change and decreased frequency of cold events (Cavanaugh et al. 2014, Stevens et al. 2006, Raabe et al. 2017).

Saltmarsh zonation is evident in distributions of sawgrass (*Cladium jamaicense*), black needlerush (*Juncus roemerianus*), and smooth cordgrass (*Spartina alterniflora*) in 2018 (Figure 4-7). The general pattern seen in this region is that smooth cordgrass occupies low-lying inundated shorelines, while black needlerush occupies a broad swath of the marsh adjacent to sawgrass, which is limited to fresher areas (Stout 1984, Wolfe 1990, Clewell et al. 2002). Smooth cordgrass is limited to areas downstream of Rkm 7 and is especially prevalent in the area where Battle Creek, Petty Creek, and Mason Creek converge. Meanwhile, black needlerush (*Juncus roemerianus*) is found throughout. Domination of salt marsh by *Juncus roemerianus* is common from Tampa Bay north to the panhandle (Raabe et al. 2017). The shoreline of the salt marsh areas along the Halls River, Price creek, Battle Creek, and Petty Creek are vegetated by sawgrass (*Cladium jamaicense*). Sloan (1956) documented *Juncus roemerianus* replacing *Cladium jamaicense* at Rkm 9.

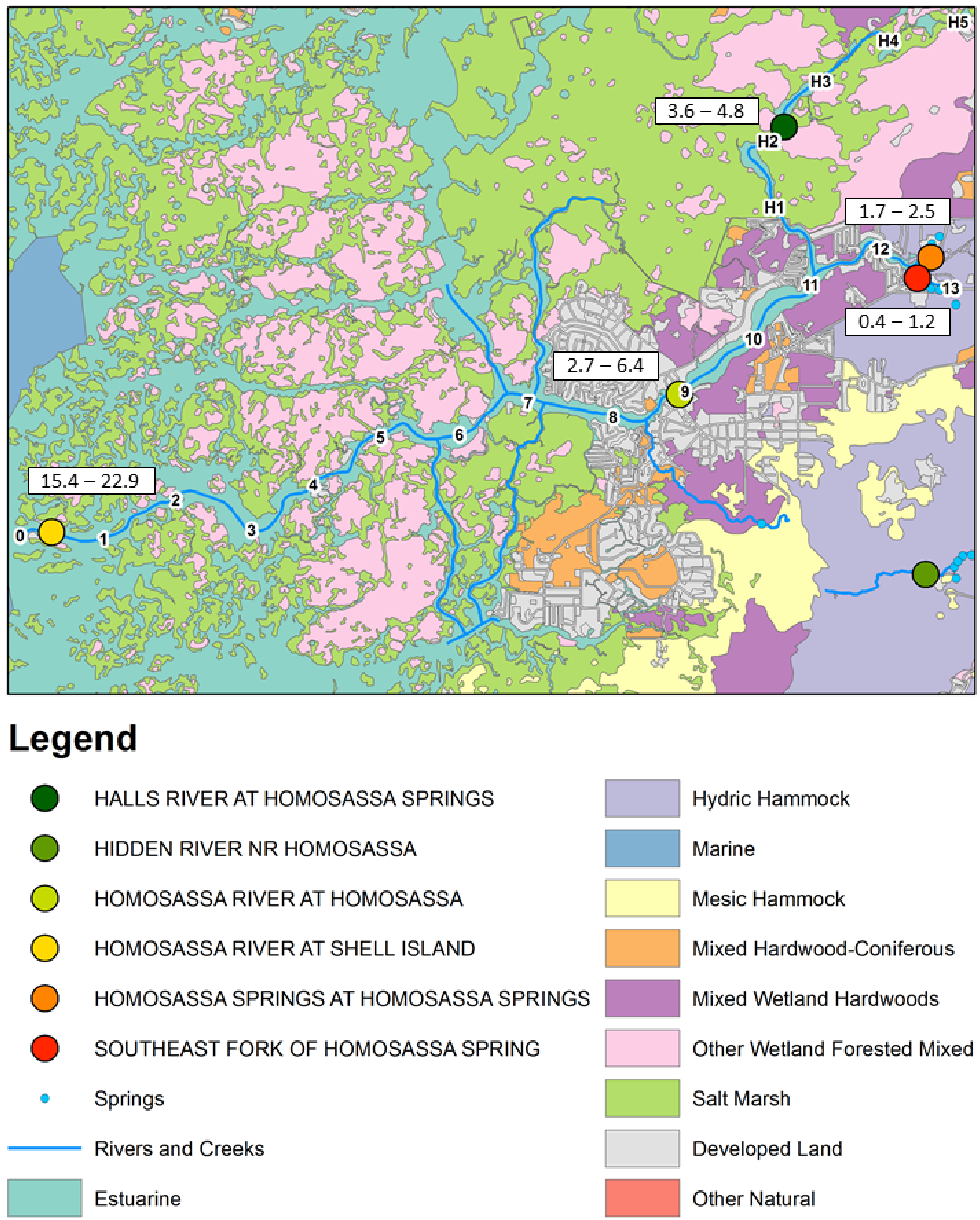


Figure 4-3. Average daily salinity range at USGS gages in the Homosassa River System, and vegetation communities from the Florida Cooperative Land Cover map (Florida Natural Areas Inventory 2016).

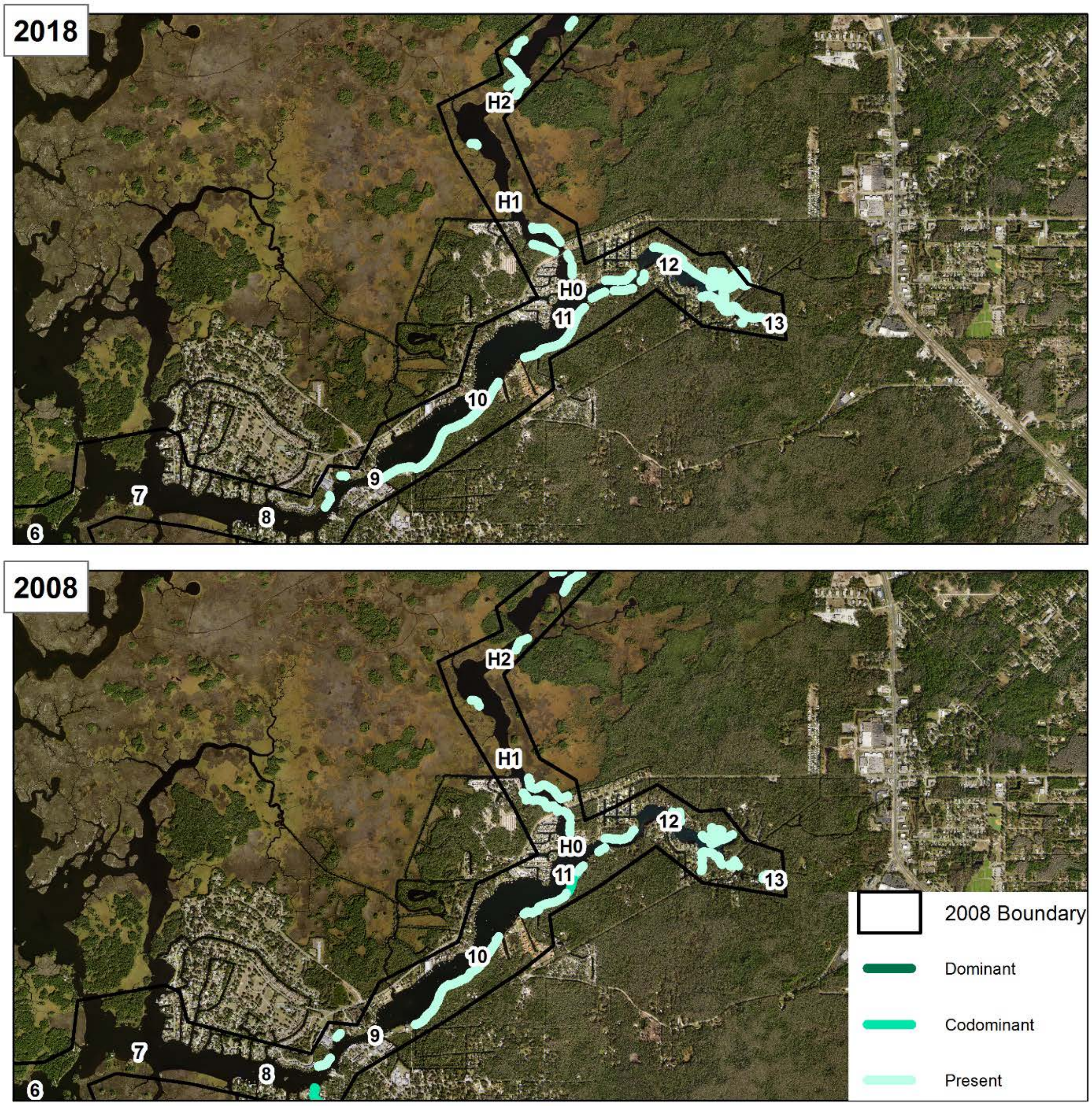


Figure 4-4. Distribution of *Acer rubrum*, *Fraxinus sp*., *Magnolia virginiana*, *Morella cerifera*, *Persea palustris*, and *Quercus laurifolia* in 2008 and 2018 surveys. Dominance, Codominance, and Presence shown combined for all 6 species. For the most part, these hardwood species do not exhibit dominance or codominance, but are part of a diverse community.

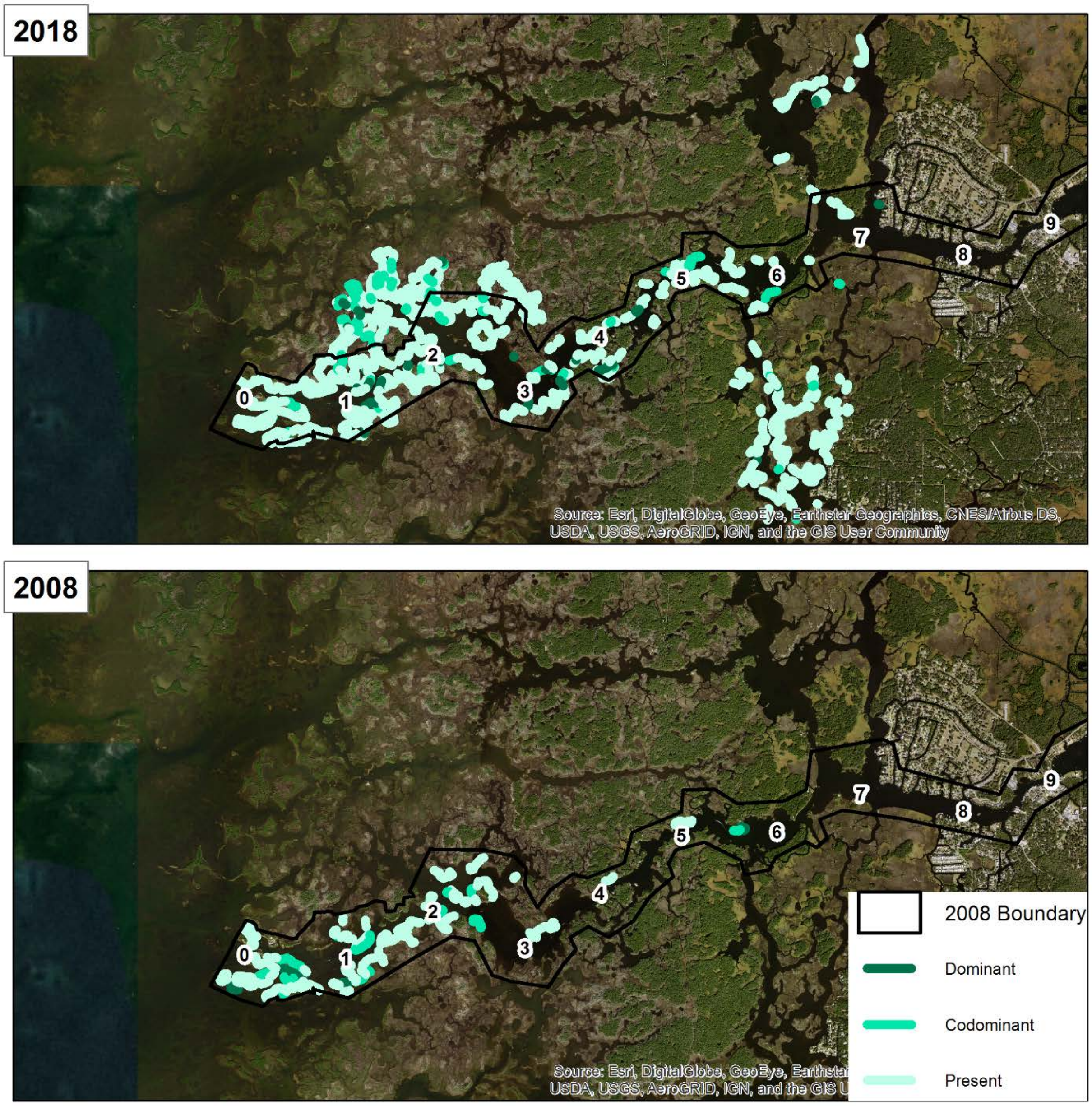


Figure 4-5. Distribution of black mangrove (*Avicennia germinans*), buttonwood (*Conocarpus erectus*), and white mangrove (*Laguncularia racemosa*) in 2008 and 2018 surveys, Dominance, Codominance, and Presence shown combined for all 6 species. White mangroves were not detected in 2008.

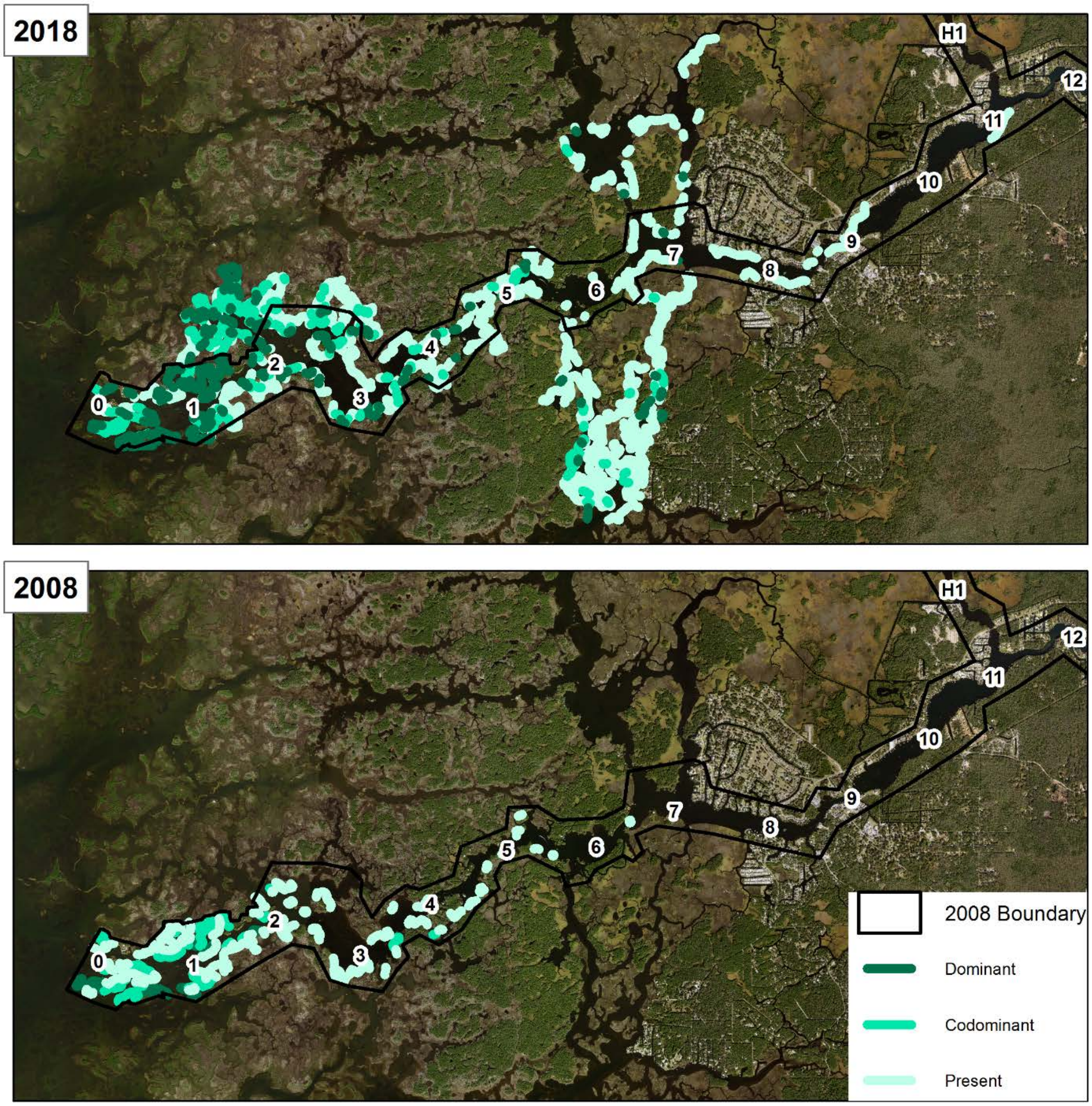


Figure 4-6. Distribution red mangroves (*Rhizophora mangle*) in 2008 and 2018.

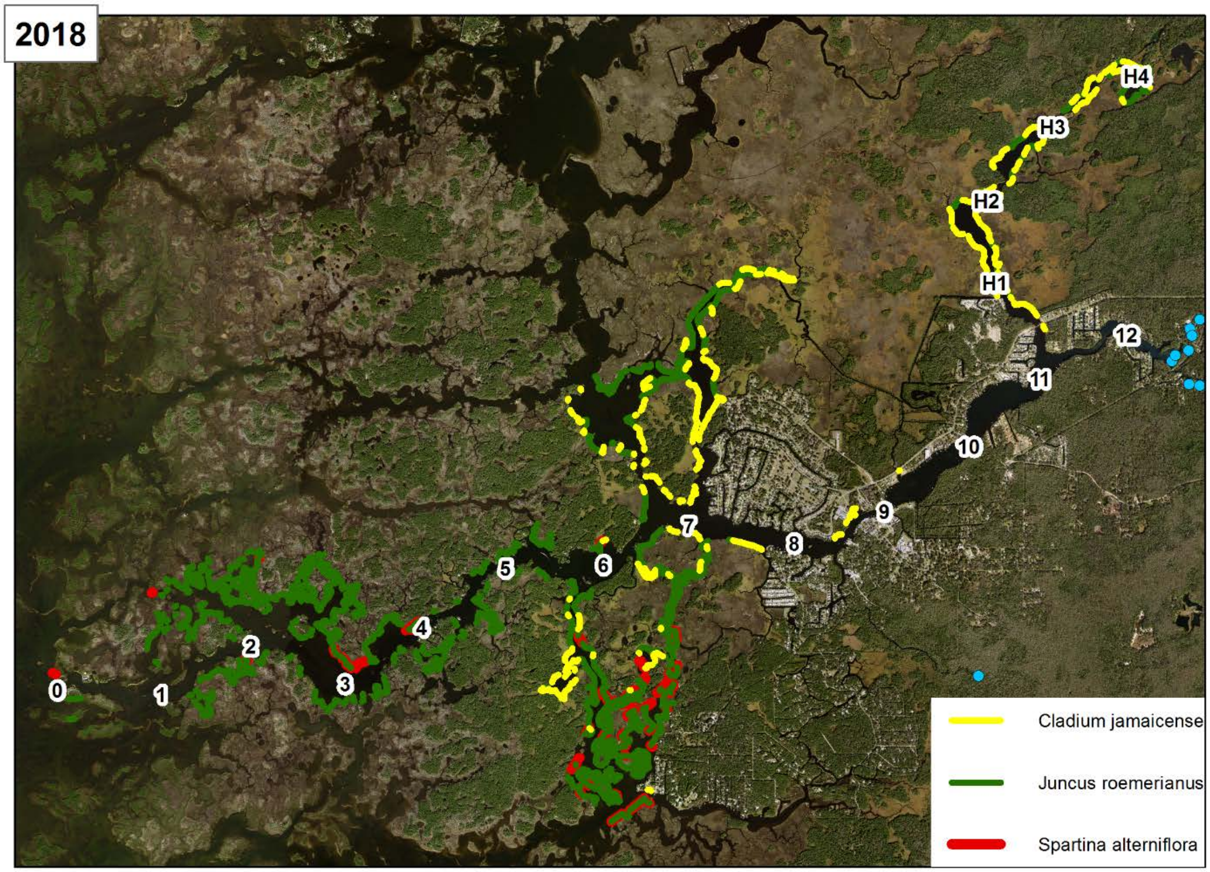


Figure 4-7. Spatial distribution of sawgrass (*Cladium jamaicense*), black needlerush (*Juncus roemerianus*), and smooth cordgrass (*Spartina alterniflora*) in 2018 (Water and Air Research, Inc. 2018a. Shown are areas where these three species are codominant or dominant (presence not shown).

4.1.3 Submerged Aquatic Vegetation (SAV)

Eelgrass (*Vallisneria americana*), sago pondweed (*Stuckenia pectinata*), and southern waternymph (*Najas guadalupensis*) covered up to seventy percent of the bottom of the Homosassa River at sampling stations from 1952 to 1954 (Sloan 1956). Sloan documented dominance and patterns of abundance changing with location, as *Vallisneria americana* dominated upstream near the spring pool, and *Stuckenia pectinata* and *Najas guadalupensis* becoming dominant 1.5 miles downstream (approx. Rkm 10.6).

Whitford (1956) reported eelgrass (*Vallisneria* sp.) and pondweed (*Potamogeton* sp.) as more abundant than *Sagittaria* sp. and waternymph (*Najas* sp.), which were in "fair abundance" in the Homosassa. Dominant algae included *Cladophora* sp. and *Enteromorpha plumosa*, which, along with the diatoms *Cocconeis placentula*, *Gomphonema longiceps*, and *Synedra ulna* made up 80% or more of the algal flora. Also found were muskgrass *Chara* sp. and *Vaucheria* sp.

The invasive watermilfoil (*Myriophyllum spicatum*) was identified in the Homosassa River in 1966 after reported release in 1964, and grew to such a thickness it impaired fishing, boating, and other recreational use (Blackburn and Weldon 1967). Watermilfoil (*M. spicatum*) and Brazilian waterweed (*Egeria densa*) were so thick, they were treated with copper sulfate in the Crystal, Homosassa, and Chassahowitzka rivers in 1967 (Gates 1967).

Frazer et al. (2001) sampled submerged aquatic vegetation in the Homosassa River during the summers of 1998, 1999, and 2000. The most common plant species found were southern waternymph (*Najas guadalupensis*), and watermilfoil (*Myriophyllum spicatum*). Other macrophytes included coontail (*Ceratophyllum demersum*), eelgrass (*Vallisneria americana*), sago pondweed (*Stuckenia pectinata*), small pondweed (*Potamogeton pusillus*), wigeon grass (*Ruppia maritima*), and *Hydrilla verticillata*. *Lyngbya* sp. and *Chaetomorpha* sp. were the most frequently occurring macroalgae, with *Gracilaria* sp, *Enteromorpha intestinalis*, and *Chara* sp. also present.

There was considerable interannual variation in distribution and abundance of submerged aquatic vegetation from 1998 to 2000 (Frazer et al. 2001). This interannual variation corresponded to variation in rainfall, with a drought in 2000 resulting in low flows and increased salinities. Frazer et al. (2001) mapped SAV in the Homosassa River, found decreasing biomass downstream, and concluded that salinity was negatively correlated with vegetative biomass. Comparison of flow rates in the Withlacoochee, Crystal, Homosassa, Chassahowitzka, and Weeki Wachee rivers showed no relationship between rates of flow and submerged aquatic vegetation or algal biomass.

Vegetation in the Homosassa River was reevaluated between during summer months (August through September) of 2003 and 2005 to compare with previous sampling efforts (Frazer et al. 2006). Compared to the previous sampling done in 1998 to 2000, there was a 67% reduction in SAV, a doubling of periphyton, and a doubling of locations with no plants or algae. These vegetative changes were coincident with increased nitrogen and phosphorus concentrations and loads, and an increase in light attenuation (i.e., reduced light at depth), but also a decrease in salinity.

Hoyer et al. (2004) concluded that light attenuation and salinity are critical for determining submerged macrophyte biomass in the Homosassa River. Macrophytes were only found where greater than 10% of light reaches bottom and where average annual salinity is less than 3.5 ppt.

Wetland Solutions, Inc. (2010) surveyed the main spring run in November 2008 and found 56% coverage of *Chaetomorpha*, 5% coverage of *Lyngbya* sp., and <1% coverage of *Najas guadalupensis*, *Ruppia maritima*, and *Zannichella palustris*.

Applied Technology and Management (2016 [Appendix 2]) surveyed SAV in the Homosassa in August and September 2015 (along with the Weeki Wachee and Chassahowitzka rivers) following the same methods as Frazer et al. (2001, 2006) so that changes could be compared (Figure 4-8). This 2016 effort also included data collected in 2011. River-wide, the 2015 mean total SAV percent cover was almost 50 percent less than the mean total SAV percent cover for all of the previous sampling events. Eelgrass (*V. americana*) was not observed at any locations in the Homosassa River System in 2015. Between 1998-2011 and 2015, total SAV biomass decreased by over 90%, SAV percent cover decreased by 50%, angiosperm biomass decreased 81%, and macroalgae biomass decreased 99%. The majority of the biomass was upstream of Rkm 11, consequently changes to biomass and coverage in this portion of the river drove overall river changes (Figure 4-9). Therefore, critical SAV habitat appears to be upstream of the confluence of the Halls and Homosassa rivers.

When considering changes to SAV coverage and species composition over many years, it is important to consider fluctuations that may occur on seasonal and other time scales. Stevenson et al. (2007) showed considerable changes to percent coverage and composition from spring to fall of 2003 in the Homosassa River. In April 2003, they found 9% aerial coverage of *Hydrilla verticillata* and 48% coverage of *Najas guadalupensis*. In November 2003, the community had shifted to 33% *Najas guadalupensis*, 2% *Lemna* sp., and 40% *Potamogeton pusillus*. Furthermore, algal coverage and community composition changed: in April 2003, algal mats consisting of 72% *Chaetomorpha* sp. and 28% *Lyngbya* sp. covered 17.3 percent of 100m downstream length surveyed with a mean thickness of 8.3 cm. By November 2003, the community had shifted to 15% *Bacillariophyta* sp., 74% *Chaetomorpha sp*., 3.5% *Enteromorpha sp*., and 7% *Spirogyra sp.* combining for 79% area coverage at 11.2 cm thick. These seasonal changes suggest that the SAV community sampled discontinuously (for example only during August and September) may not accurately represent the community as it changes through the course of a year. Therefore, comparisons across years based on discontinuous sampling may miss important patterns in community composition, biomass, and area coverage.

Comprehensive reviews of seagrass communities in the area include those by Zieman and Zieman (1989), Frazer and Hale (2001), Mattson *et al.* (2007) and Dawes *et al.* (2004). Zieman and Zieman (1989) describe gulf coast seagrass distribution, biology, community structure, ecological processes, and human impacts in a 102-page report by the US Fish and Wildlife Service. Frazer and Hale (2001) were contracted by the District to analyze aerial photographs for changes in abundance and distribution of SAV along the springs coast. Mattson et al. (2007) is a chapter in a USGS report on status and trends in seagrass distribution and health along the Big Bend coast of Florida. Dawes et al. (2004) reports on a joint project to update Zieman and Zieman (1989) by synthesizing information on the biology and ecology of seagrasses including status and trends in distribution, autecology, communities, and human consequences.

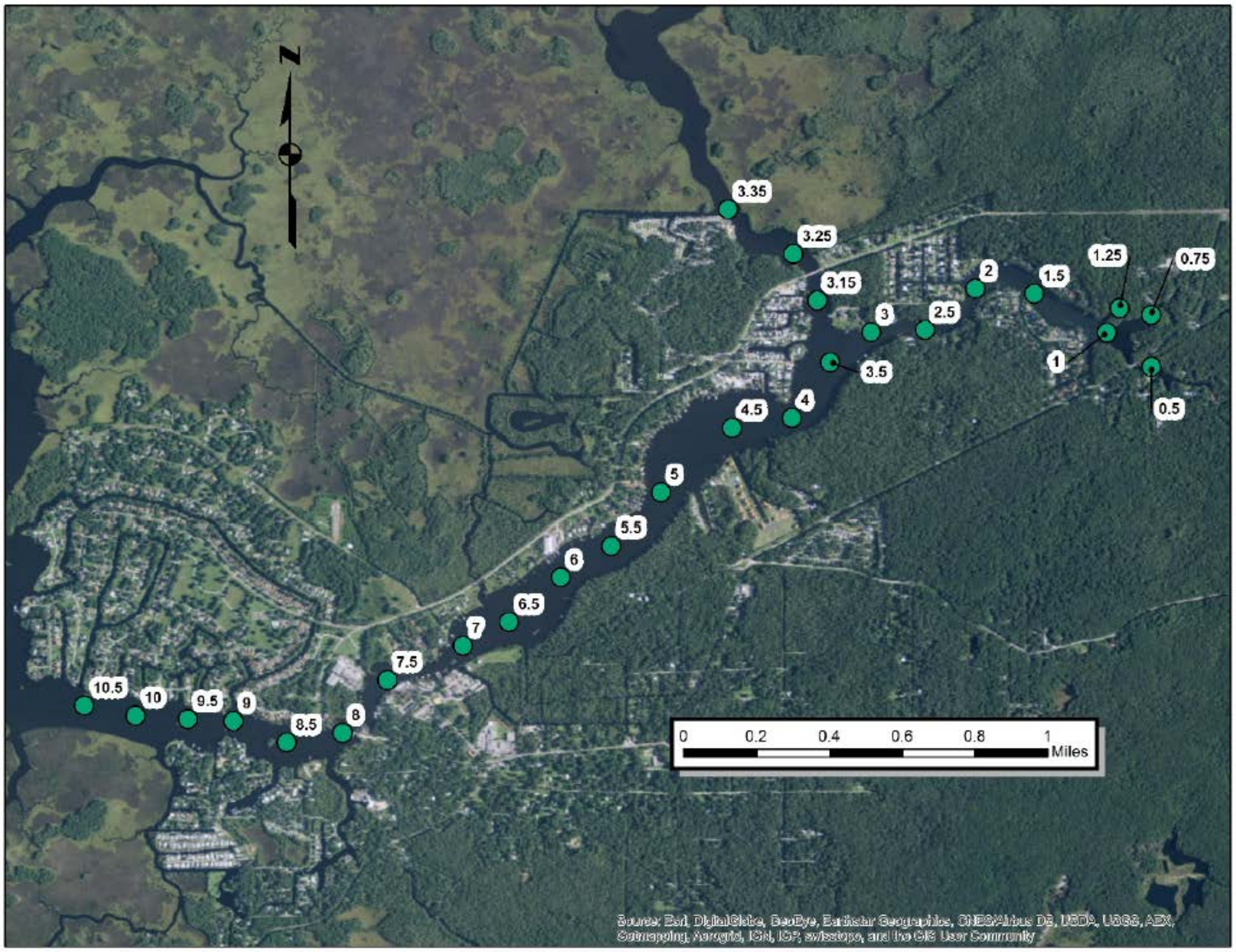


Figure 4-8. Transect locations for SAV sampling in the Homosassa River System in 2015 (Applied Technology and Management 2016).

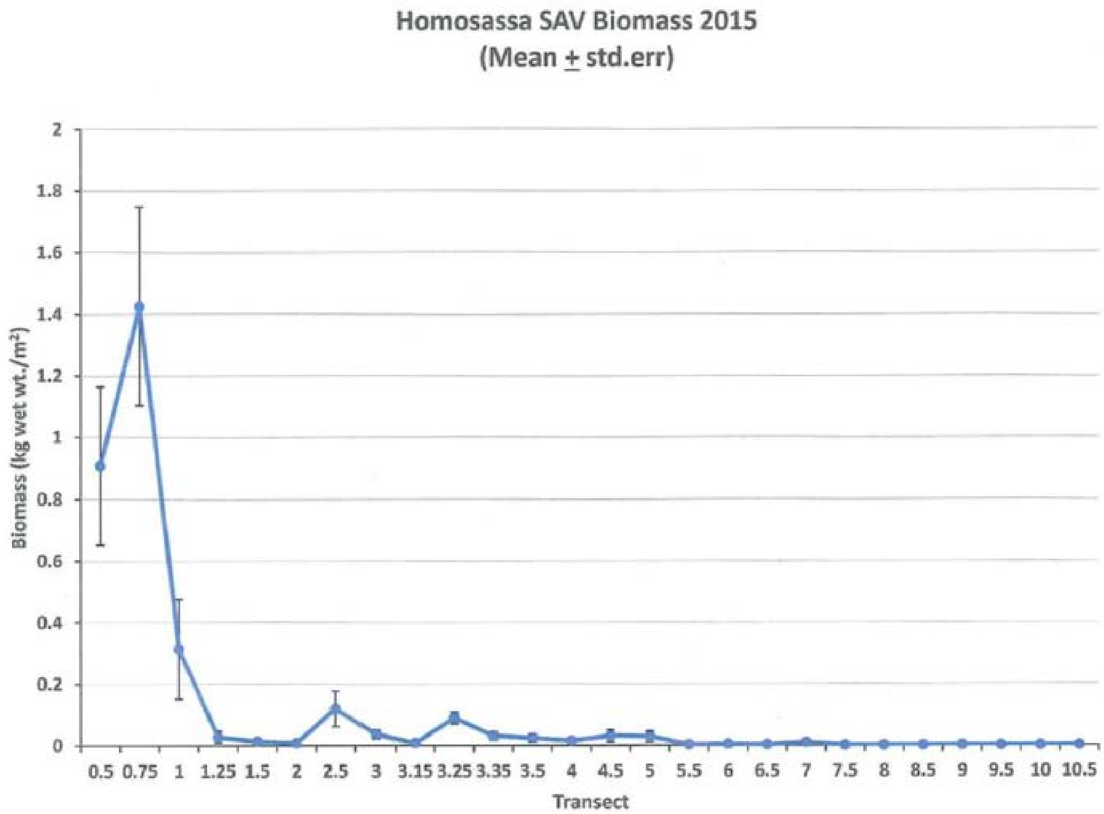


Figure 4-9. Profile of SAV biomass in the Homosassa River in 2015.

4.1.4 Effects of Salinity and Sea Level on Vegetation

Shoreline and emergent plant species distributions are limited by a combination of salt stress tolerance and competition (Crain et al. 2004). Both saltwater plants and freshwater plants tend to flourish when grown alone in fresh water. However, freshwater plants outcompete saltwater plants when in combination. Saltwater plants are able to tolerate salt stress better than freshwater plants. Therefore, plant zonation in estuaries is caused by a combination of competitive displacement in freshwater reaches and stress tolerance in saltwater reaches.

In seven southwestern Florida estuaries, the distribution of shoreline vegetation is linked to salinity (Clewell et al. 2002). There is a consistent pattern of transition from less salt tolerant species in headwater areas to more salt tolerant species toward the Gulf of Mexico. However, salinity is not the only driver of community composition. Competition and disturbance also play roles in determination of which species are found in any location. Moreover, salinity varies in time over tidal periods, over years, with rainy years experiencing lower salinities, and with storms which drive higher salinities landward during storm surges. These factors combine to affect the zonation apparent in shoreline vegetation.

Freshwater hardwoods in the Homosassa River System are limited to the upper reaches, presumably by their salt tolerance (Figure 4-4). Meanwhile salt tolerant species are limited to saltier reaches where their stress tolerance allows them to proliferate without competition by less tolerant species (Figure 4-5). Thus, it is important to manage salinity habitat for emergent and shoreline species as shifts in salinity habitat are predicted to result in salt stress at the individual level and alter shoreline habitats at the community level.

Sea level rise has led to the invasion of marsh grasses into the lower parts of the hammock islands that dot salt marshes on the Gulf coast of Florida. The presence of former islands is marked by groups of trunks of dead cabbage palms (the most salt tolerant of the upland trees in the area) standing in the middle of what is now salt marsh (Williams et al. 1999). Die-offs of cabbage palm and red cedar in coastal hydric hammocks near Waccasassa Bay have been attributed to sea level rise – which causes chronic stress and limits regeneration – and storm events – which produce acute stress and kill adult trees (Williams et al. 2003).

Sea level rise has resulted in expansion of marshes and decrease in area of forested wetlands in gulf coast of Florida, with forest retreat reduced in areas with greater freshwater input (Raabe and Stumpf 2015). Sea level rise and drought are responsible for declines in coastal hydric hammocks, in particular *Sabal palmetto* and *Juniperus virginiana* distribution and abundance (DeSantis et al. 2007). Continued sea-level rise is expected to result in continued loss of habitat and declines in spatial abundance of species and the communities they form. Castaneda and Putz (2007) documented a 17.5% decrease in coastal forest area in the Waccasassa Bay State Preserve between 1973 and 2003; these forests were replaced by salt marsh. Sea level rise is expected to continue this trend of forest loss and conversion to salt marsh (Doyle et al. 2010).

4.1.5 Vegetation Summary

Natural communities surrounding the Homosassa River System include upland forests, freshwater forested wetlands, salt marshes, and coastal forests. These communities, and their constituent species are constrained by their tolerance for abiotic factors including frequency and duration of inundation and exposure to salinity. The species occupying the shoreline of this system were mapped in 2012, and this mapping was repeated in greater detail and extent in 2018. These species each have ranges of salinity tolerance that dictate where they are found. Changes to the salinity regime are expected to shift the composition of species bordering the Homosassa River System.

Submerged aquatic vegetation in the Homosassa has declined since the first quantification of abundance in 1998. Earlier records also report more extensive SAV coverage, though only qualitatively. However, SAV is known to shift seasonally, and the SAV community may recover more quickly than emergent or terrestrial communities might be expected to.

Sea level rise has caused die-off of *Sabal palmetto*, *Juniperus virginiana*, and their coastal hydric hammock community (Williams et al. 2003). Net loss of coastal forests and conversion of forests to salt marsh are expected to continue with sea level rise, but some of this may be mitigated by continued freshwater input to the system.

4.2 Benthic Macroinvertebrates

4.2.1 Oysters

The District contracted Water and Air Research, Inc. (2018b [Appendix 10]) to survey oysters in the Homosassa River in 2018. The sampling protocol was focused on assessing oyster condition at representative sites along the Homosassa River with the goal of determining physical, chemical, and biological determinants of oyster distribution, abundance and health (Water and Air Research, Inc. 2018b). A condition index, which is a relative measure based on the ratio of tissue mass to internal volume was used to assess oyster health (Water and Air Research, Inc. 2018b and references therein). The oyster sampling effort was not a comprehensive mapping survey. Rather, oyster bars were identified and mapped using aerial photographic interpretation that was complemented by field surveys and ground truthing (Water and Air Research, Inc. 2018b).

Oyster bars were found from Rkm 0 to Rm 5 along the mainstem of the river, and along Petty, Battle, and Mason Creeks (Figure 4-10). Oyster bars were sampled for condition in three zones, an upper zone located between Rkm 5 and 7 in Petty and Battle Creeks, a middle zone between Rkm 2 and 3, and a lower zone between Rkm 1 and 2. Oysters in sampled bars averaged 21 alive out of 25 sampled, with 301 per 10 x 10 cm quadrat. There were no statistically significant differences in oyster density or percent living between the three zones. Oyster condition index was greater in the upper zone (median = 9.24) than in the middle (7.61) and lower zone (7.25). Oyster condition index values from Zones B and C did not differ.

4.2.2 Barnacles

Similar to the oyster effort, barnacles were surveyed to find representative sites along the river but were not comprehensively mapped. Barnacles were searched for on existing hard substrates within every Rkm and sampled if they were present on suitable substrate. Areas with suitable substrate, but with no or few barnacles present were located and recorded with a GPS. Only intertidal or shallow subtidal areas were searched visually from the boat or by walking along the shoreline.

Examples of locations surveyed include navigation aids, signs, docks, seawalls, and trees. At 8 sample collection sites, 25 barnacles within a 10 by 10 cm quadrat were measured and assessed as live or dead (Figure 4-11). All barnacles within the quadrat were then collected for laboratory measurement. the number of barnacles at each location ranged from 8 to 80. Four upstream sites were considered oligohaline and 4 downstream sites were mesohaline. There were no statistical differences in number, percent alive, diameter, dry weight, and percent organic matter between oligohaline and mesohaline sites. There was an average of 73 barnacles per 100 cm^2, 55 percent of which were alive, with a mean diameter of 5.81 mm. There were no significant rank correlations in barnacle metrics with river kilometer.

Five sites in the Halls river had an average of 70.4 barnacles per 100 cm^2, 83% percent alive, with a mean diameter of 8 mm.

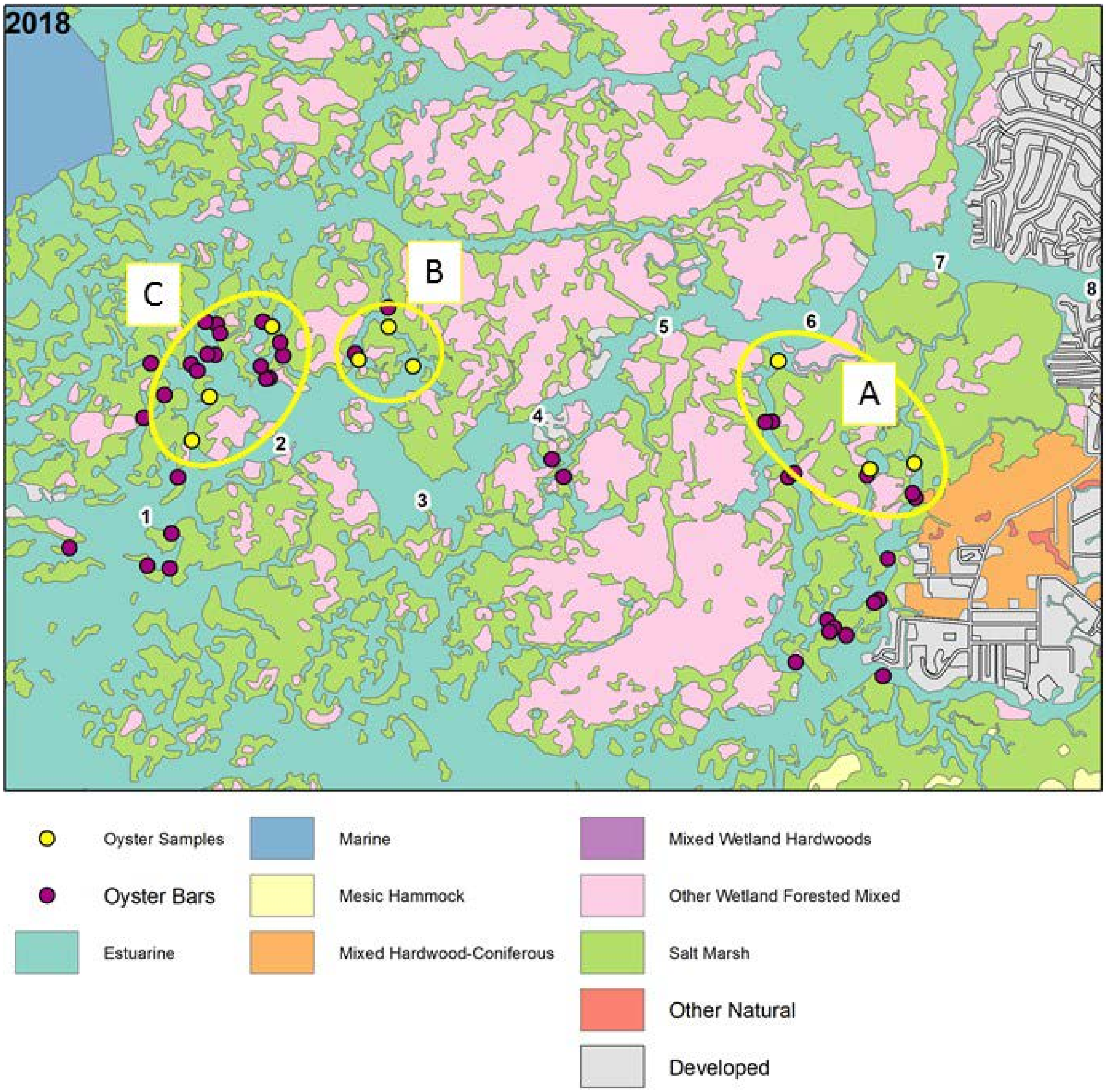


Figure 4-10. Oyster bar locations in the Homosassa River System in 2018. Comparison of oyster locations with background vegetation shows oysters are found in saltmarsh areas.

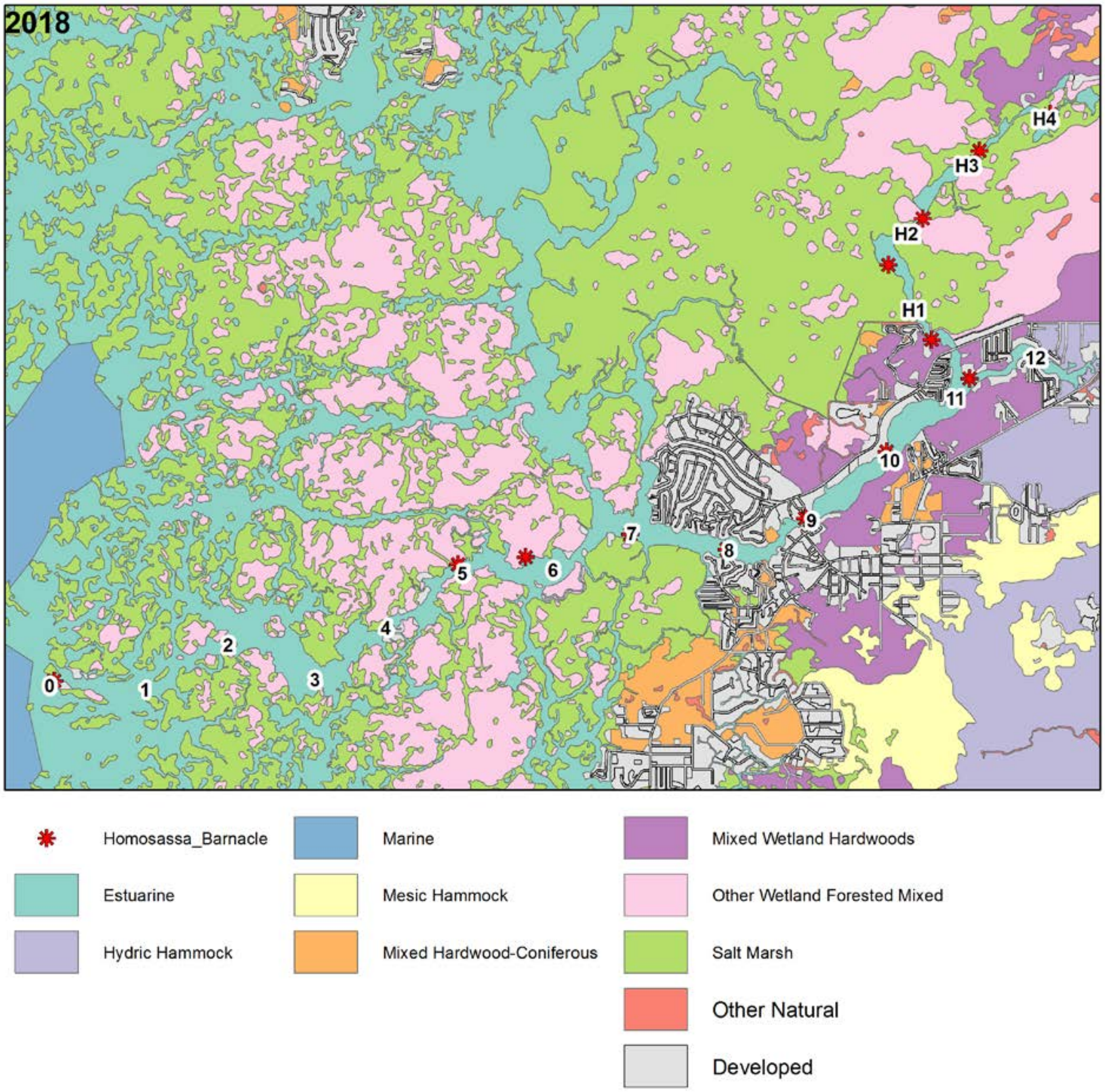


Figure 4-11. Barnacle sampling locations in the Homosassa River in 2018.

4.2.3 Blue Crab

The Blue Crab, *Callinectes sapidus*, is an ecologically and economically valuable estuarine-dependent species that can be found from the waters of Argentina in the southern hemisphere to Massachusetts in the northern hemisphere. Blue Crabs use a wide range of habitats depending on the physiological requirements of each stage of their life cycle. Their life cycle includes planktonic, nektonic, and benthic stages. Mating occurs inshore, in low-salinity waters (<15 psu), where juvenile females undergo their pubertal molt, mate with mature males, and then migrate offshore (higher salinities; >30 psu) to spawn (Gandy et al. 2011). In Florida, Blue Crab mating occurs during spring and summer; although mating has been recorded in fall and winter months with spawning delayed until the following spring or when water temperatures rise to 19°C. March to November are also the months when Blue Crab megalopae (one of their planktonic stages) return from oceanic waters into the estuaries through tidally-related vertical migration. Once in the estuary, they settle in marshes and SAV for their metamorphosis into first-crab stage. Although early juveniles can be found in lower bay sites, large juveniles have been reported in lower-salinity waters, which suggests an upstream migration into oligohaline marshes and SAV beds (Gandy et al. 2011).

The FWC is the authority responsible for managing Blue Crab harvesting in Florida. Female Blue Crabs may be harvested lawfully if they are not bearing eggs. Since female Blue Crabs can only mate once, releasing them unharmed will help support the Blue Crab population (visit myFWC.com for fisheries regulations). Although fishing rates and Blue Crab landings in the state of Florida have been on a general downward trend since the 1990s, the predicted stock status does not suggest either coast of Florida to be overfished or undergoing overfishing (Cooper et al. 2013). Fisheries-independent studies also report steady trends in juvenile and adult stocks (FWRI-FIM 2016). It's been noted that Blue Crab stocks in the Eastern Gulf of Mexico (i.e., Florida) generally peak in years following high rainfall (GDAR 2013, FWRI-FIM 2016).

Over the course of several decades, FWC and the University of South Florida have conducted numerous studies relating abundance, location, and community dynamics to freshwater inflow. Gandy et al. (2011) summarized the results and discussed the limitations of these and other regional studies. No consistent direct relationships between Blue Crabs and quantity of freshwater flow have been found. Of particular concern is the fact that in the Homosassa River System, Blue Crab nekton increased with increasing flow, while the opposite response was detected int eh nearby Chassahowitzka River System (Peebles et al. 2009). Results from 12 years of fish and invertebrate sampling in the Alafia River showed that an abundance/flow regression approach with 2-5 years of data is insufficient to quantify a consistent predicable response (Wessel 2012). Wessel (2012) evaluated a moving 2-year window of sampling results for several taxa commonly found in west Florida tidal rivers. This report found that for a given taxa there was little consistency in the predicted number of organisms as a function of flow and response reversed often. Wessel (2012) notes that "only with at least 4 years of data collection did the slope estimates tend to stabilize toward a particular direction, and in several instances, 4 years of data was not enough to achieve statistical significance." Wessel (2012) added that "together, these issues regarding the existing analytical methods to establish the fish-flow relationship revealed that more work was needed to describe the effects of freshwater inflows on fish abundance in tidal rivers". Similarly, a literature review by the Gulf States Marine Fisheries Commission (GDAR 2013) suggests that studies showing positive relations to freshwater inflows used long-term, life-history based data, over a larger spatial component, while results with negative relations were generated when using data from an individual river.

The endangered Whooping Crane (*Grus americana*) overwinters in the southeastern United States, including the Chassahowitzka National Wildlife refuge in Florida (WCEP 2016). Recognizing that the Blue Crab is an important food source for these endangered birds, the District contracted with FWC to review the local relationships between Blue Crab and freshwater inflows (Gandy et al. 2011). Blue Crab population dynamics are dependent on many factors including nutrient loading, productivity, pollution, predator displacements, and their effects on habitat (Gandy et al. 2011). Alterations in freshwater inflows have the potential to impact available habitat for Blue Crab life stages, through alterations to salinity zonation (Gandy et al. 2011). Therefore, ensuring there are no significant changes to salinity habitats will protect Blue Crab populations from adverse effects of reduced flows on salinity.

4.2.4 Historical Macroinvertebrate Surveys

The invertebrate fauna of the Homosassa River has been sampled on numerous occasions by various research groups. These studies have shown that a diverse assemblage of macroinvertebrates including crustaceans, mollusks, and insects occurs in the river. Studies have also shown that benthic macroinvertebrate taxa are sensitive indicators of salinity.

Sloan (1956) collected insects using dip net sampling every six weeks from November 1952 to February 1954. Representative species of the orders Diptera (flies), Ephemeroptera (mayflies), Trichoptera (caddisflies), Hemiptera (true bugs), Coleoptera (beetles), Lepidoptera (butterflies and moths), and Odonata (dragonflies). Species richness (number of species), and abundance (total number of insects) is low at the pool – correlating with low dissolved oxygen concentration, increases in the run immediately downstream of the pool, and decreases downstream toward the estuary – which correlates with the longitudinal salinity gradient.

Janicki Environmental Inc. (JEI 2007) conducted a meta-analysis of invertebrate sampling efforts in 12 rivers on the gulf coast of Florida: Peace River, Shell Creek, Myakka River, Manatee River, Little Manatee River, Alafia River, Tampa Bypass Canal, Lower Hillsborough River, Weeki Wachee River, Crystal River, Withlacoochee River, and the Waccasassa River. They found the polychaete *Laeonereis culver* and the isopod *Edotea triloba* in greater than 90 percent of these rivers, and the amphipod *Grandidierella bonnieroides*, the polychaete worms *Streblospio gynobranchiata* and *Paraprionospio pinnata*, and the bivalve *Amygdalum papyrium* in more than 80 percent of the rivers. Communities were able to be grouped by geographical locations. Communities were also grouped by salinity classes, with midges of the family Chironomidae and worms of the class Polychaeta and of the subclass Oligochaeta common at salinities less than 8 ppt. Community structure appeared to be influenced by salinity and sediment type. The authors concluded that complex models that deal with issues of high-level interactions and non-linearity tend to yield complex solutions which do not yield straightforward management actions. In other words, when simple linear relationships between organisms and flow are not found, searching for more complex analytical relationships will not yield the simple linear trends that may have been originally sought.

Montagna et al. (2008) conducted a meta-analysis of data on salinity and mollusks in 10 southwest Florida rivers. They parameterized nonlinear regressions to predict mollusk abundance from salinity. Results indicate that all rivers had different communities of mollusks due to differing salinity regimes. The authors assert that freshwater inflow, which controls salinity, is an important determining factor for species presence and abundance. Species demonstrated strong preferences for salinity ranges, allowing for grouping into oligohaline, mesohaline, and polyhaline zones. The invasive bivalve *Corbicula fluminea* was the best indicator of freshwater habitat. They conclude that mollusk assemblages will change in response to changing salinity regimes as a result of alterations to freshwater inflow.

Frazer et al. 2011 sampled at five stations each on 3 reaches in the Chassahowitzka and Homosassa rivers in 2007, 2008, 2009, and 2010. The density and biomass of invertebrates associated with SAV was greatest during winter sampling periods when filamentous algae biomass was high (Figure 4-12). Many taxa demonstrated a higher abundance during periods with high biomass of filamentous algae, with the exception of insect larvae and pupae. Insect density and biomass was similar across all sampling periods in the Chassahowitzka River; however, Frazer et al. (2011) observed a relatively high biomass of insects in the Homosassa River during February 2008 when filamentous algae mats were prevalent. Insects, particularly chironomids, were abundant in both filamentous algae and macrophyte samples, which may explain why density and biomass remained high during summer periods in the Chassahowitzka River which provides year-round SAV habitat. Of the taxa measured in invertebrate samples, amphipods and Blue Crabs demonstrated the greatest biomass, with peak biomass occurring during winter periods (Figure 4-13). Additionally, Blue Crabs demonstrated an increase in biomass during May and June, coincident with large-scale production of filamentous algae in the Homosassa River. One surprising result was the observed increase in density and biomass of gastropods associated with filamentous algae in the Homosassa River.

Grabe and Janicki (2010) sampled at 104 stations in the Homosassa River System on 12-14 May 2008. They found the benthos is a diverse assemblage comprised of taxa generally similar to those of other Springs Coast tidal rivers (JEI 2007). The benthos of the Homosassa and Halls rivers was dominated by amphipod crustaceans. Dominant taxa in the two rivers differed due to differences in salinity. The Homosassa Main Spring Run and Southeast Fork also included communities which were distinguishable from other portions of the system. Numbers of taxa, diversity, and density varied with river kilometer (Figure 4-14). Individual taxa demonstrated optimal and preferred salinity ranges. They predicted that if spring flows were reduced such that saline waters were to intrude upriver, numbers of taxa and diversity would increase, chironomids would decrease, and the amphipod *Ampelisca* sp., the tanaid *Kalliapseudes macsweeneyi*, and various polychaetes and gastropods would penetrate further upriver.

Water and Air Research, Inc. (2010) identified 3 oyster beds and sampled mollusks by spade and Ponar dredge on September 30 September and 1 October 2008. They found less abundance and diversity than Grabe and Janicki (2010), which they speculate was a result of a less intensive sampling effort.

Wetland Solutions, Inc. (2010) sampled emergence during three days in November 2008. They found representatives of orders Diptera and Trichoptera, with greater abundance in the spring run than pool. Only the spring run and pool were sampled, and only during three days; this was not intended as a comprehensive survey of the invertebrate fauna.

Culter 2010 sampled from March to July 2009 focusing on upstream reaches. Barnacle settlement in the river appears to be inhibited by salinities less than 2 ppt, but barnacles were present at these low salinities. This suggests that once settled, barnacles can tolerate low salinity waters. The main spring run was devoid of barnacles. In the upper reaches of the river, barnacles were found near the bottom where salinities are higher, rather than in the intertidal zone, where barnacles typically occur.

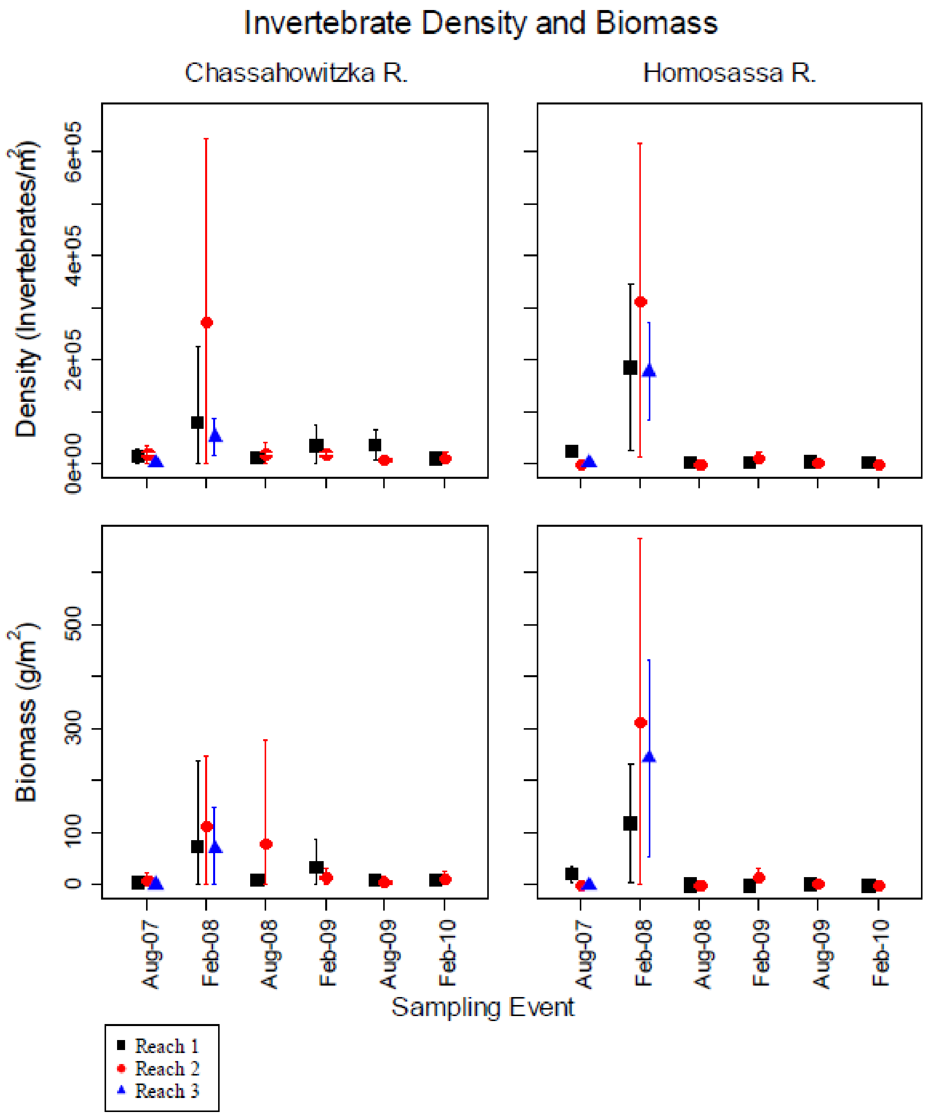


Figure 4-12. Biomass and density of invertebrates in the Homosassa and Chassahowitzka rivers from Frazer et al. (2011).

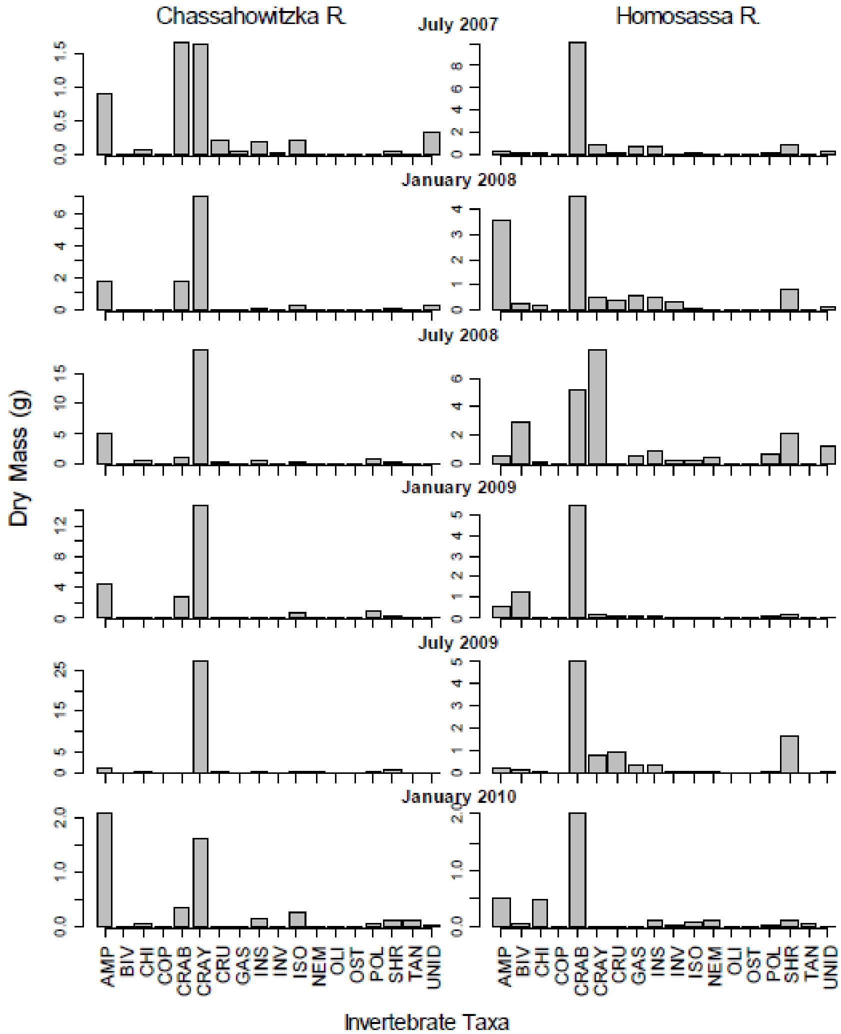


Figure 4-13. Invertebrate taxa in the Homosassa and Chassahowitzka rivers reported by Frazer et al. 2011. AMP=Amphipods, BIV=Bivalve, CHI=Chironomid Larvae, COP=Copepod, CRAB=Crabs, CRAY=Crayfish, CRU=Unidentified Crustacean, GAS=Gastropod, INS=Other Insect Larvae, INV=Other Invertebrate, ISO=Isopod, NEM=Nematode, OLI=Oligochaete, OST=Ostracod, POL=Polychaete, SHR=Shrimp, TAN=Tanaid, UNID=Unidentified Invertebrate

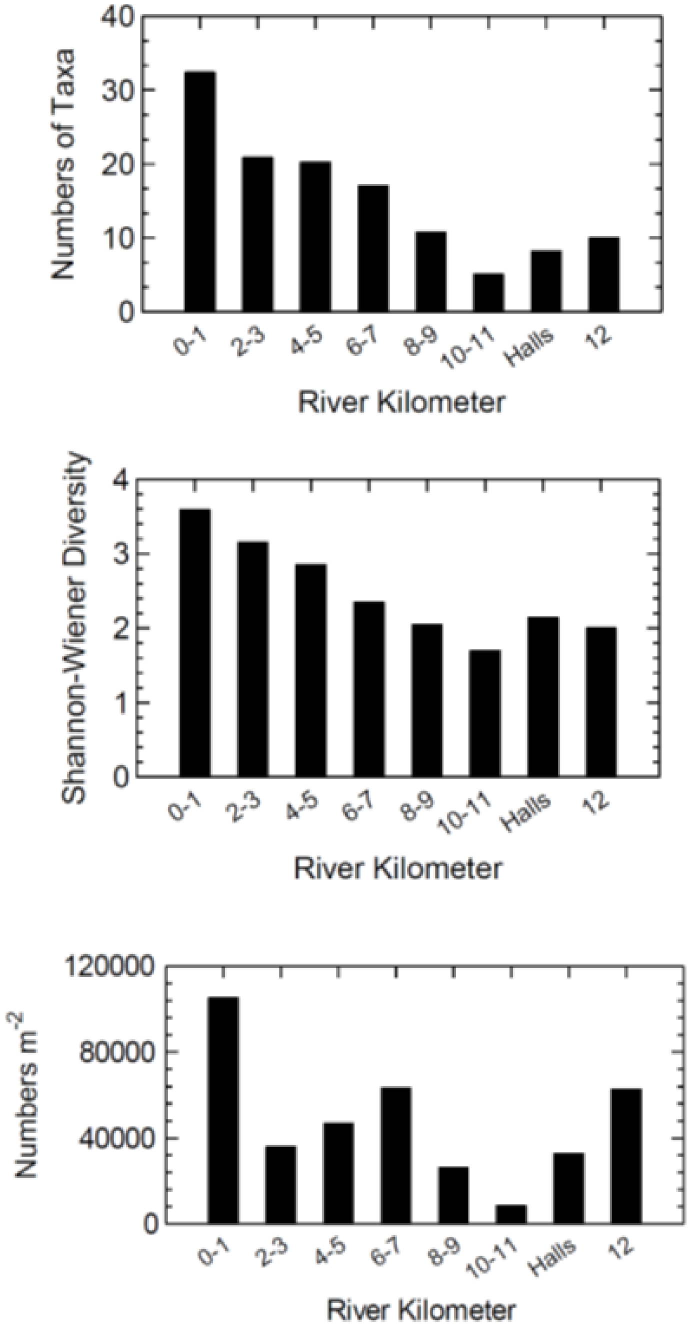


Figure 4-14. Numbers of taxa, diversity, and density varied by river kilometer in the Homosassa River System (from Grabe and Janicki 2010).

4.2.5 2016 Coastal Rivers Invertebrate Analysis

The District contracted Amec Foster Wheeler & Infrastructure, Inc. (2016 [Appendix 1]) to sample macroinvertebrates in the Homosassa River System. The study area included the area beginning at the Homosassa headspring, the main stem of the Homosassa River, Halls River, and the Southeast Fork of the Homosassa River. Eleven sampling zones were determined based on salinity gradients and hydrologic contributions to the mainstem of the river. One headspring zone, one SE Fork zone, three zones upstream of the Halls River, three zones downstream of the Halls River, and three zones on Halls River were identified (Figure 4-15). At each of the sampling sites within the zones, and based on existing habitats, above-sediment SAV, rock, snag and macroalgae samples were collected with a D-Frame dipnet. Each macroinvertebrate sample was collected by sweeping the D-frame net a total of four times (0.125 m^2 each), for a total sample area of 0.5 m^2 for each habitat. Petite ponar (0.023 m^2) was used to collect a quantitative sample of macroinvertebrates from bare sediment.

Amec Foster Wheeler Environment & Infrastructure, Inc. (2016) identified the 15 macroinvertebrate taxa with the highest dominance scores. Of these 15 taxa, 3 were annelid worms, 7 were crustaceans, 4 were midges, and 1 was a gastropod. Five taxa made up 63% of the organisms collected from the Homosassa River: the amphipods *G. bonnieroides* and *A. louisianum*; the tanaid Leptocheliidae spp.; the midge *Dicrotendipes* spp.; and the polychaete worm *L. culveri*. In Halls River, the top five taxa constituted 65% of the organisms: Hydrobiidae spp. snails; the tanaid Leptocheliidae spp.; the amphipods *Gammarus* spp. and *A. louisianum*; and the polychaete worm *L. culveri*.

Habitat type was used as a factor to evaluate trends in invertebrate community structure among macroalgae, rock, sediment, SAV and snag habitats in the sampled rivers (Amec Foster Wheeler Environment & Infrastructure, Inc. 2016). Snag habitat displayed the highest total species richness of 142 taxa, followed by SAV and macroalgae (which had the same species richness of 118 taxa). Sediment and rock habitat had similar taxa richness with 86 and 84 taxa, respectively. The dominant taxon found in the macroalgae samples was the amphipod *Hyalella azteca* sp. complex making up 49% of the organisms found in macroalgae samples. Hydrobiidae snails are the second most dominant taxon in the macroalgae samples. Dominant taxa found in the rock samples were Leptocheliidae tanaids, followed by the amphipod *G. bonnieroides*. Dominant taxa found in the SAV samples were the midges *Tanytarsus* spp. and *Cricotopus/Orthocladius* spp. making up 22% and 12% of the organisms found in all of the SAV samples, respectively. Dominant taxa found in the sediment samples were the amphipod *G. bonnieroides* and Tubificinae worms making up 20% and 15% of the total organisms found in all of the sediment samples, respectively. Dominant taxa found in snag samples were Leptochellidae tanaids, followed by the amphipod *A. louisianum,* making up 30% and 22% of the total organisms found in all snag samples, respectively. Invertebrate species richness and diversity indices were correlated with water temperature, salinity, turbidity, canopy cover, and habitat diversity (Table 4-1). This result links macroinvertebrate community structure to salinity and temperature habitats modeled by LAMFE. Insect taxa were more common in fresher water, while annelid worms were more abundant in saltier water (Table 4-2).

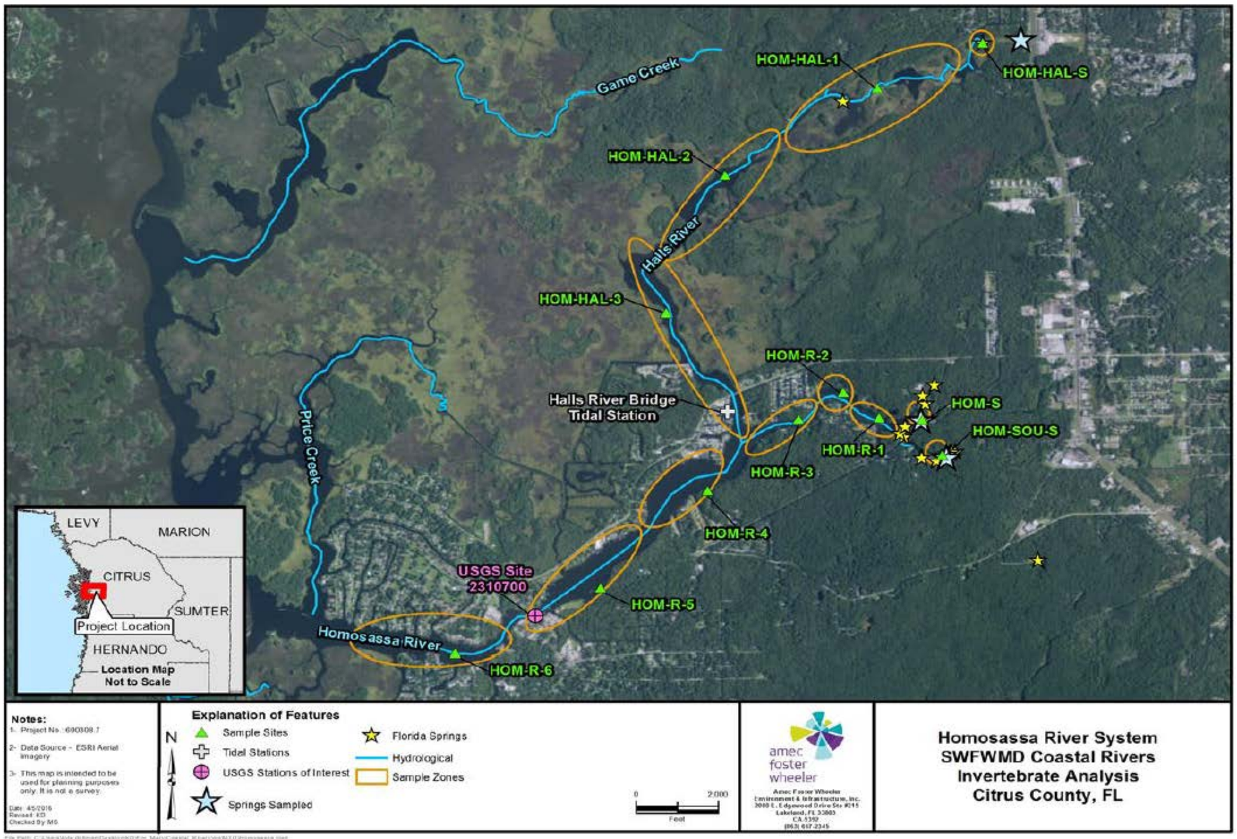


Figure 4-15. Invertebrate sampling sites used in 2015 by Amec Foster Wheeler Environment & Infrastructure, Inc. (2016).

Table 4-1. Spearman's rank correlation results for macroinvertebrate community metrics and habitat characteristics in the Weeki Wachee, Homosassa, and Chassahowitzka rivers (from Amec Foster Wheeler Environment & Infrastructure, Inc. 2016).

Physical-Chemical Parameters	Richness (# of taxa)	Abundance (total # of individuals/m^2)	Margalef's Richness Index (d)	Pielou's Evenness Index (J')	Shannon's Diversity Index (H'(loge))	Simpson's Diversity Index (1-Lambda')
Water Temperature (°C)	Rho = -0.287 p = 0.112	Rho = -0.071 p = 0.688	**Rho = -0.404 p = 0.022**	Rho = 0.0148 p = 0.418	Rho = -0.125 p = 0.495	Rho = -0.029 p = 0.877
Dissolved Oxygen (mg/L)	Rho = 0.056 p = 0.763	Rho = 0.008 p = 0.967	Rho = -0.073 p = 0.691	Rho = -0.054 p = 0.767	Rho = 0.052 p = 0.779	Rho = 0.012 p = 0.949
Dissolved Oxygen (%)	Rho = 0.024 p = 0.896	Rho = -0.001 p = 0.995	Rho = -0.109 p = 0.554	Rho = -0.038 p = 0.834	Rho = 0.034 p = 0.854	Rho = -0.002 p = 0.991
Salinity (ppt)	**Rho = -0.354 p = 0.047**	Rho = -0.071 p = 0.700	**Rho = -0.410, p = 0.020**	Rho = 0.299 p = 0.097	Rho = -0.036 p = 0.846	Rho = 0.155 p = 0.398
Conductivity (µS/cm)	**Rho = -0.421 p = 0.016**	Rho = -0.020 p = 0.914	**Rho = -0.494 p = 0.004**	Rho = 0.303 p = 0.092	Rho = -0.064 p = 0.726	Rho = 0.155 p = 0.397
pH (SU)	Rho = 0.035 p = 0.851	Rho = 0.002 p = 0.991	Rho = -0.061 p = 0.741	Rho = -0.112 p = 0.540	Rho = 0.001 p = 0.995	Rho = -0.042 p = 0.818
Turbidity (NTU)	**Rho = -0.351 p = 0.049**	Rho = -0.133 p = 0.467	**Rho = -0.422 p = 0.016**	Rho = 0.157 p = 0.392	Rho = -0.099 p = 0.590	Rho = -0.005 p = 0.978
Canopy Cover (%)	**Rho = 0.383 p = 0.031**	Rho = -0.228 p = 0.209	**Rho = 0.625 p = 0.000**	Rho = 0.031 p = 0.865	Rho = 0.307 p = 0.088	Rho = 0.187 p = 0.306
Habitat Diversity	**Rho = 0.420 p = 0.017**	Rho = 0.207 p = 0.255	**Rho = 0.501 p = 0.004**	Rho = -0.316 p = 0.078	Rho = 0.151 p = 0.409	Rho = -0.030 p = 0.869

Note: Rho is the correlation coefficient, bolded cells are considered to be statistically significant at $p<0.05$.

Table 4-2. Spearman's rank correlations for major taxonomic groups for Weeki Wachee, Homosassa, and Chassahowitzka rivers (from Amec Foster Wheeler Environment & Infrastructure, Inc. 2016).

Percentage of Major Taxonomic Group by Zone	Salinity ppt	Conductivity µS/cm	Water Temperature °C	Turbidity NTU	Dissolved Oxygen %
Acari	**-0.530**	**-0.505**	-	-	-
	0.002	*0.003*	*NS*	*NS*	*NS*
Annelida	**0.421**	**0.368**	-	**0.354**	-
	0.017	*0.038*	*NS*	*0.047*	*NS*
Coleoptera	**-0.609**	**-0.612**	**-0.480**	**-0.575**	-
	0.000	*0.000*	*0.005*	*0.001*	*NS*
Diptera	-	**-0.349**	**-0.384**	**-0.509**	-
	NS	*0.050*	*0.030*	*0.003*	*NS*
Ephemeroptera	**-0.613**	**-0.659**	**-0.491**	**-0.688**	-
	0.000	*0.000*	*0.004*	*0.000*	*NS*
Heteroptera	**-0.377**	**-0.376**	-	-	-
	0.033	*0.034*	*NS*	*NS*	*NS*
Lepidoptera	**-0.519**	**-0.531**	**-0.453**	**-0.560**	-
	0.002	*0.002*	*0.009*	*0.001*	*NS*
Trichoptera	**-0.701**	**-0.732**	**-0.637**	**-0.740**	**-0.362**
	0.000	*0.000*	*0.000*	*0.000*	*0.042*
Odonata	**-0.546**	**-0.542**	-	**-0.473**	-
	0.001	*0.001*	*NS*	*0.006*	*NS*

Note: The top bolded value in each cell is Rho, the correlation coefficient. The bottom value in italics is the p-value. All results reported in this table are considered to be statistically significant at $p<0.05$

4.3 Fish and Invertebrate Plankton and Nekton

4.3.1 Electrofishing from Dec. 2013 to May 2018

Under contract with the District, the FWC sampled the fish community in the Homosassa River on 36 dates during 11 events from December 2013 through May 2018 (Table 4-3) (Johnson et al. 2017, [Appendix 8]). The FWC divided the Homosassa into three salinity zones (corresponding roughly to Rkm 11-12, Rkm 9.5 – 11, and Rkm 8 - 9.5) with a total of 168 transects measuring 100 m each and running parallel to the shoreline (Johnson et al. 2017) (Figure 4-16).

A total of 55 fish species from 29 families were caught (

Table 4-4). Across all sampling dates, the four most common fish were saltwater species: Tidewater Mojarra, Gray Snapper, Common Snook, and Striped Mullet (Figure 4-17). The fifth, sixth, and seventh most common species were the freshwater Largemouth Bass, Bluegill, and Spotted Sunfish.

Table 4-3. Fish sampling effort in the Homosassa River by FWC (Johnson et al. 2017).

Event	Start	Finish	Season	Distance (m)	Sites
1	2013-12-09	2013-12-11	Winter	2990	30
2	2014-06-02	2014-06-04	Summer	2800	28
3	2015-01-05	2015-01-07	Winter	3000	30
4	2015-06-01	2015-06-03	Summer	3000	30
5	2015-08-17	2015-08-19	Summer	2900	29
6	2015-11-16	2015-11-18	Winter	3000	30
7	2016-06-13	2016-06-15	Summer	2900	29
8	2016-11-29	2016-12-01	Winter	2900	29
9	2017-08-07	2017-08-10	Summer	2700	27
10	2017-11-27	2017-12-01	Winter	3000	30
11	2018-05-14	2018-05-17	Summer	2900	29

Figure 4-16. Zones for fish sampling in the Homosassa River from (Johnson et al. 2017).

Table 4-4. Species list with abundance in the Homosassa River from December 2013 to December 2017. CPUD = catch per unit distance (km), % = percent of total abundance, C.% = cumulative percent of catch.

Scientific Name	Common Name	Family	Habitat	Count	Rank	%	C.%
Eucinostomus harengulus	Tidewater Mojarra	Gerreidae	Salt	3787	1	33.5	33.5
Lutjanus griseus	Gray Snapper	Lutjanidae	Salt	2885	2	25.5	59.1
Centropomus undecimalis	Common Snook	Centropomidae	Salt	973	3	8.6	67.7
Mugil cephalus	Striped Mullet	Mugilidae	Salt	707	4	6.3	73.9
Micropterus salmoides	Largemouth Bass	Centrarchidae	Fresh	504	5	4.5	78.4
Lepomis macrochirus	Bluegill	Centrarchidae	Fresh	338	6	3	81.4
Archosargus probatocephalus	Sheepshead	Sparidae	Salt	246	7	2.2	83.6
Lepomis punctatus	Spotted Sunfish	Centrarchidae	Fresh	236	8	2.1	85.7
Lagodon rhomboides	Pinfish	Sparidae	Salt	224	9	2	87.6
Anchoa mitchilli	Bay Anchovy	Engraulidae	Salt	197	10	1.7	89.4
Menidia beryllina	Inland Silverside	Atherinopsidae	Fresh	174	11	1.5	90.9
Harengula jaguana	Scaled Sardine	Clupeidae	Salt	103	12	0.9	91.8
Brevoortia sp.	Menhaden	Clupeidae	Salt	91	13	0.8	92.7
Lucania parva	Rainwater Killifish	Fundulidae	Fresh	87	14	0.8	93.4
Sciaenops ocellatus	Red Drum	Sciaenidae	Salt	85	15	0.8	94.2
Lepisosteus platyrhincus	Florida Gar	Lepisosteidae	Fresh	83	16	0.7	94.9
Lepomis microlophus	Redear Sunfish	Centrarchidae	Fresh	67	17	0.6	95.5
Gambusia holbrooki	Eastern Mosquitofish	Poeciliidae	Fresh	47	18	0.4	95.9
Strongylura marina	Atlantic Needlefish	Belonidae	Salt	43	19	0.4	96.3
Arius felis	Hardhead Catfish	Ariidae	Salt	40	20	0.4	96.7
Trinectes maculatus	Hogchoker	Achiridae	Salt	33	21	0.3	96.9
Pogonius cromis	Black Drum	Sciaenidae	Salt	31	22	0.3	97.2
Strongylura timucu	Timucu	Belonidae	Salt	30	23	0.3	97.5
Anguilla rostrata	American Eel	Anguillidae	Fresh	29	24	0.3	97.7
Mugil curema	White Mullet	Mugilidae	Salt	29	24	0.3	98
Leiostomus xanthurus	Spot	Sciaenidae	Salt	24	25	0.2	98.2
Microgobius gulosus	Clown Goby	Gobiidae	Salt	23	26	0.2	98.4
Dasyatis sabina	Atlantic Stingray	Dasyatidae	Salt	19	27	0.2	98.6

Caranx hippos	Crevalle Jack	Carangidae	Salt	17	28	0.2	98.7
Lucania goodei	Bluefin Killifish	Fundulidae	Fresh	17	28	0.2	98.9
Eucinostomus sp.	Mojarra	Gerreidae	Salt	12	29	0.1	99
Notemigonus crysoleucas	Golden Shiner	Cyprinidae	Fresh	12	29	0.1	99.1
Elops saurus	Ladyfish	Elopidae	Salt	11	30	0.1	99.2
Myrophis punctatus	Speckled Worm Eel	Ophichthidae	Salt	10	31	0.1	99.3
Lepisosteus osseus	Longnose Gar	Lepisosteidae	Fresh	8	32	0.1	99.4
Poecilia latipinna	Sailfin Molly	Poeciliidae	Fresh	8	32	0.1	99.4
Remora sp.	Remora	Echeneidae	Salt	8	32	0.1	99.5
Cynoscion nebulosus	Spotted Seatrout	Sciaenidae	Salt	7	33	0.1	99.6
Gobiosoma bosc	Naked Goby	Gobiidae	Salt	7	33	0.1	99.6
Lepomis sp.	Sunfish	Centrarchidae	Fresh	7	33	0.1	99.7
Syngnathus scovelli	Gulf Pipefish	Syngnathidae	Salt	7	33	0.1	99.7
Fundulus seminolis	Seminole Killifish	Fundulidae	Fresh	6	34	0.1	99.8
Notropis petersoni	Coastal Shiner	Cyprinidae	Fresh	5	35	0	99.8
Opsanus beta	Gulf Toadfish	Batrachoididae	Salt	5	35	0	99.9
Fundulus confluentus	Marsh Killifish	Fundulidae	Salt	2	36	0	99.9
Strongylura notata	Redfin Needlefish	Belonidae	Salt	2	36	0	99.9
Erimyzon sucetta	Lake Chubsucker	Catostomidae	Fresh	1	37	0	99.9
Eucinostomus gula	Silver Jenny	Gerreidae	Salt	1	37	0	99.9
Eugerres plumieri	Striped Mojarra	Gerreidae	Salt	1	37	0	99.9
Fundulus grandis	Gulf Killifish	Fundulidae	Salt	1	37	0	100
Heterandria formosa	Least Killifish	Poeciliidae	Fresh	1	37	0	100
Lepomis gulosus	Warmouth	Centrarchidae	Fresh	1	37	0	100
Notropis harperi	Redeye Chub	Cyprinidae	Fresh	1	37	0	100
Oligoplites saurus	Leatherjacket	Carangidae	Salt	1	37	0	100
Pomoxis nigromaculatus	Black Crappie	Centrarchidae	Fresh	1	37	0	100

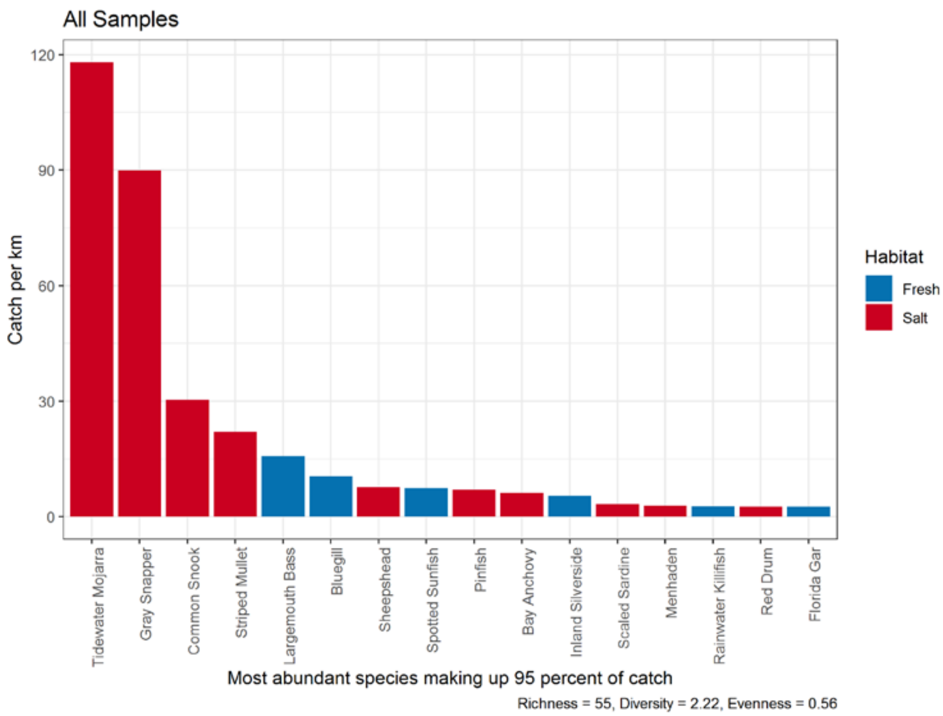


Figure 4-17. Sixteen species account for more than 95 percent of the total catch in the Homosassa River from December 2013 to May 2018 reported by Johnson et al. (2017).

4.3.1.1 Seasonal differences

Fish in the Homosassa River were sampled over six summers and five winters by the FWC (Table 4-3). In the summer, Tidewater Mojarra, Striped Mullet, and Common Snook were the most common saltwater fish (Figure 4-18). Largemouth Bass were the third most common fish overall in summer, and Bluegill, Inland Silverside, and Spotted Sunfish rounded out the common freshwater fish catch. The winter catch was dominated by saltwater fish, with Gray Snapper, Tidewater Mojarra, Common Snook, and Striped Mullet making up the majority of the catch (Figure 4-19).

The fish assemblage in summer is more diverse, richer, and more even than in winter. (Table 4-5). The differences in summer and winter communities can be seen by comparing abundance of the most common species (Figure 4-20). The difference between summer and winter communities is significant (Table 4-6). Gray Snapper, Tidewater Mojarra, Common Snook, Largemouth Bass, and Striped Mullet contribute most to dissimilarity between summer and winter assemblages (Table 4-7). In the winter, saltwater Tidewater Mojarra, Gray Snapper, and Common Snook become more common. While these saltwater fish become more common in winter, freshwater fish decline in abundance, and we see reductions in Largemouth Bass, Bluegill, and Spotted Sunfish. Thus, the assemblage appears to shift from a mix of salt and freshwater fish in the summer to a predominantly marine community in the winter. As discussed below, it is particularly important for Common Snook to be able to move into this estuary for warm water refuge in the winter.

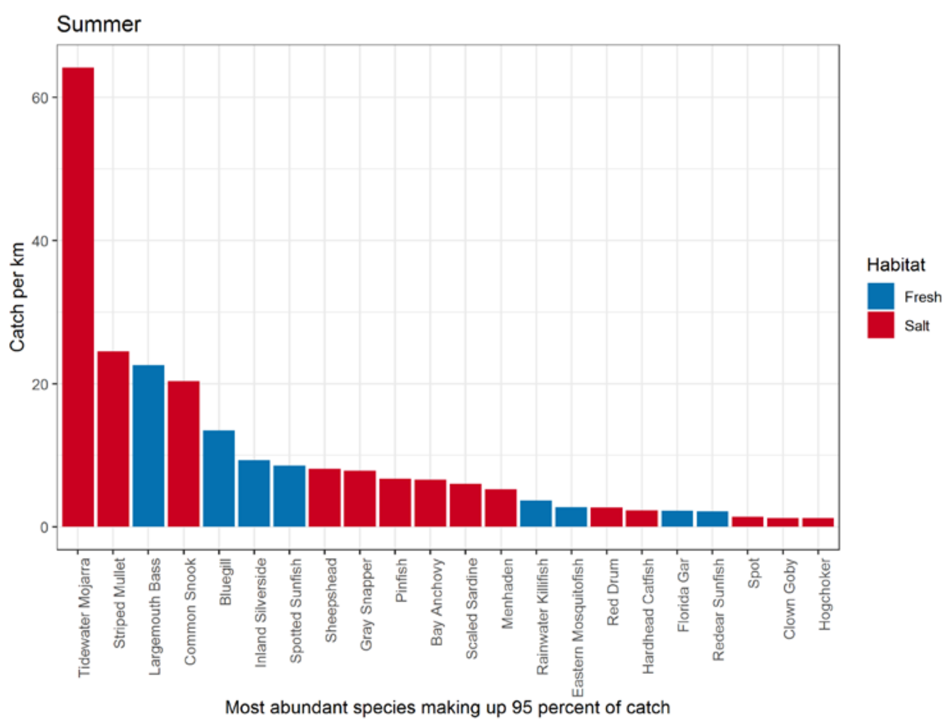


Figure 4-18. Twenty-one fish species account for greater than 95 percent of the total catch in summer sampling events in the Homosassa River reported by Johnson et al. (2017).

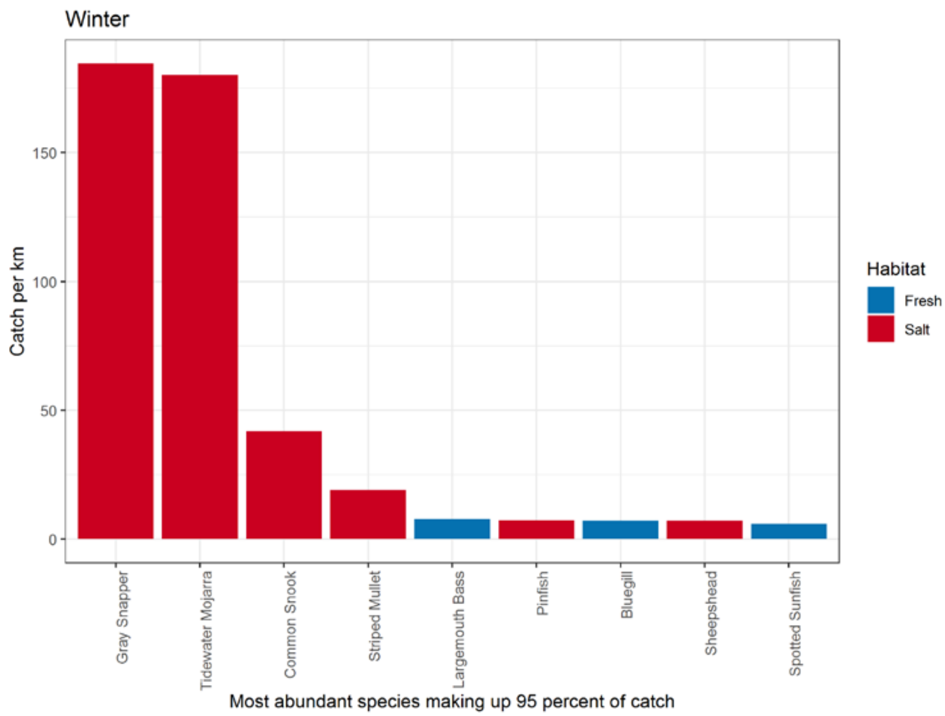


Figure 4-19. Nine fish species account for over 95 percent of the winter catch in the Homosassa River reported by Johnson et al. (2017).

Table 4-5. Fish species richness, diversity, and evenness in summer and winter catch in the Homosassa River reported by Johnson et al. (2017).

Season	Richness	Shannon Diversity	Evenness
Summer	50	2.7	0.70
Winter	36	1.7	0.47

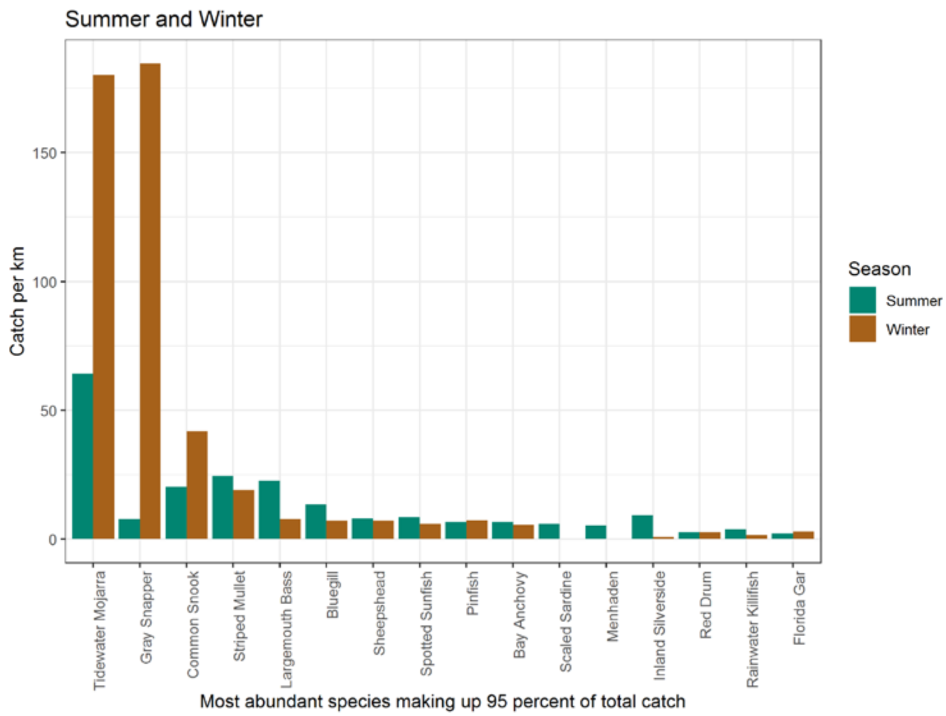


Figure 4-20. Most abundant fish species in the Homosassa River by season based on sampling reported by Johnson et al. (2017).

Table 4-6. Results of test for similarity between summer and winter fish communities in the Homosassa River based on sampling reported by Johnson et al (2017). Significance level of sample statistic = 0.1%, indicating that there is a significant statistical difference between summer and winter.

One-Way - A			
Resemblance worksheet			
Name: Resem1			
Data type: Similarity			
Selection: All			
Factors			
Place	Name	Type	Levels
A	Season	Unordered	2
Season levels			
Summer			
Winter			
Tests for differences between unordered Season groups			
Global Test			
Sample statistic (R): 0.298			
Significance level of sample statistic: 0.1%			
Number of permutations: 999 (Random sample from 1037158320)			
Number of permuted statistics greater than or equal to R: 0			

Table 4-7. Similarity percentages (SIMPER) for individual species between summer and winter fish communities in the Homosassa River based on sampling reported by Johnson et al. (2017). Analysis based on log transformed catch per unit effort and Bray-Curtis similarity using Primer. The average cumulative dissimilarity is 51.68.

Species	Summer Average Abundance	Winter Average Abundance	Average Dissimilarity	Dissimilarity /SD	Contributing %	Cumulative%
Lutjanus griseus	1.08	3.29	5.44	1.66	10.52	10.52
Eucinostomus harengulus	2.49	3.50	3.22	1.10	6.24	16.75
Centropomus undecimalis	2.12	1.93	2.95	1.31	5.71	22.47
Micropterus salmoides	2.02	0.93	2.93	1.63	5.68	28.14
Mugil cephalus	2.27	1.42	2.69	1.57	5.20	33.34
Menidia beryllina	1.04	0.12	2.33	1.07	4.51	37.85
Lagodon rhomboides	1.14	0.64	2.30	1.36	4.45	42.30
Lepomis punctatus	1.17	0.71	2.22	1.46	4.30	46.60
Lepomis macrochirus	1.33	0.87	2.15	1.43	4.17	50.77
Archosargus probatocephalus	1.28	0.79	2.04	1.34	3.94	54.72
Anchoa mitchilli	0.52	0.36	1.66	0.77	3.21	57.92
Brevoortia sp.	0.65	0.00	1.48	0.65	2.87	60.79
Lucania parva	0.71	0.27	1.48	1.21	2.86	63.65
Lepisosteus platyrhincus	0.71	0.48	1.35	1.14	2.61	66.26
Arius felis	0.55	0.00	1.34	0.66	2.60	68.86
Sciaenops ocellatus	0.58	0.33	1.24	1.30	2.40	71.27

4.3.1.2 Location Differences

Three spatial zones were identified for the Homosassa River fish sampling, numbered in order going downstream, so that zone 1 is the most upstream and zone 3 is the most downstream (Figure 4-16). Fish species richness is slightly higher in zone 2 (Table 4-8). Saltwater Gray Snapper, Tidewater Mojarra, and Striped Mullet are abundant in the upstream, zone 1, but freshwater species, dominated by Largemouth Bass, Bluegill, and Spotted Sunfish were also abundant and diverse (Figure 4-21). Zone 2 exhibits more dominance by saltwater species (Figure 4-22). Saltwater species exhibited their highest abundance in Zone 3 (Figure 4-23). The saltwater assemblage in zone 3 differs from that in the other zones, with Bay Anchovy, Pinfish, Sheepshead, and Menhaden among the most common species.

Table 4-8. Location differences in richness, diversity, and evenness.

Zone	Richness	Shannon Diversity	Evenness
1	41	2.3	0.61
2	45	2.1	0.55
3	41	2.1	0.57

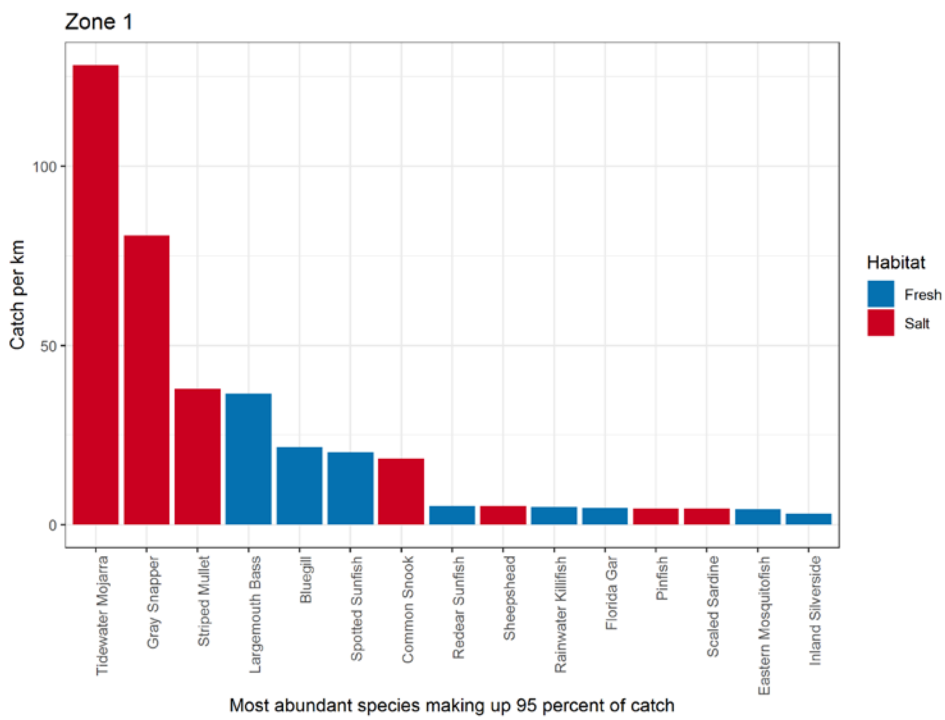


Figure 4-21. Most abundant fish species making up 95% of catch in zone 1 of the Homosassa River System as reported by Johnson et al. (2017).

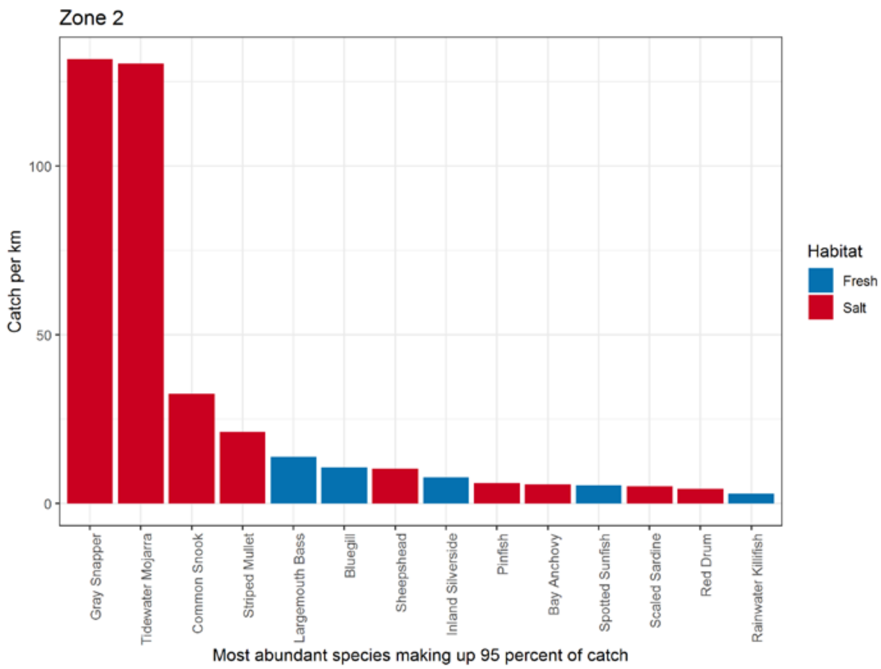


Figure 4-22. Most abundant fish species making up 95% of catch in zone 2 of the Homosassa River System as reported by Johnson et al. (2017).

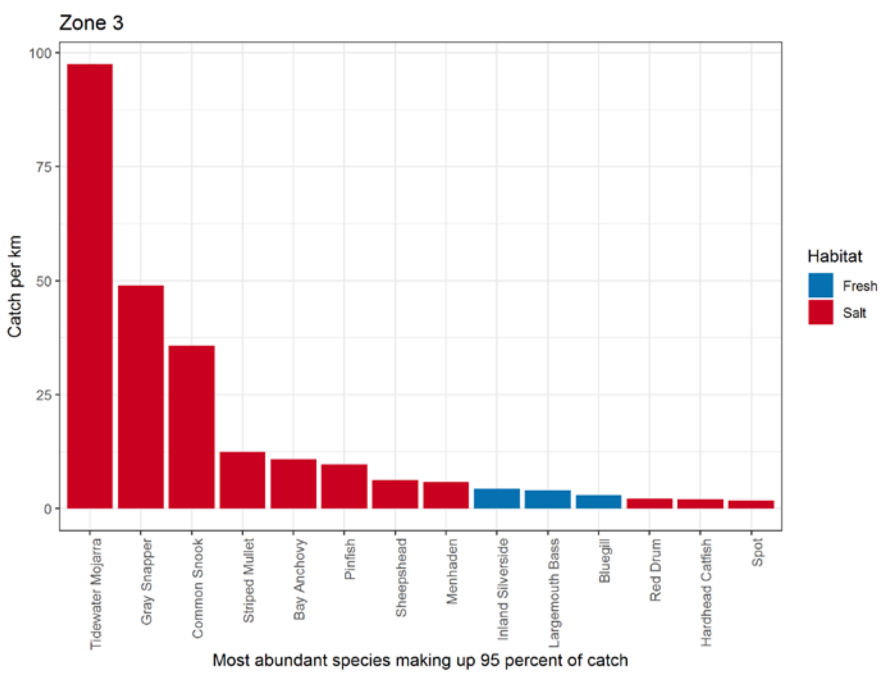


Figure 4-23. Most abundant fish species making up 95% of catch in zone 3 of the Homosassa River System as reported by Johnson et al. (2017).

4.3.1.3 Electrofishing Summary

The fish community in the Homosassa River changes from summer to winter. In summer, freshwater fish are common, and include Largemouth Bass and various sunfish such as Bluegill, Spotted Sunfish, and Redear Sunfish. In winter, saltwater fish swim upriver from the Gulf of Mexico and dominate catch (Figure 4-19). Tidewater Mojarra are numerous in both seasons, but are more abundant in winter, whereas Gray Snapper are much less common in summer, but are the most abundant winter species (Figure 4-20). Saltwater fish can be numerous in the upstream zone 1, but they are more abundant further downstream (Figure 4-21, Figure 4-22, Figure 4-23).

The Homosassa River fish community is rich with 55 species and divers (Shannon Diversity Index of 2.22), with a mixture of freshwater and saltwater species. Saltwater species are common throughout but are more numerous closer to the Gulf of Mexico. Likewise, saltwater fish can be caught at any time of year but are more common in winter.

4.3.2 Historical surveys

Fish species presence from 2013 through 2017 can be compared to previous sampling efforts (Table 4-9). Most species were caught multiple times, but some were unique to particular sampling efforts (Johnson et al. 2017). Species captured by only one of these studies include Harper’s Minnow (Herald and Strickland 1949); Tadpole Madtom (Walsh and Williams 2003); Brown Bullhead, Chain Pickerel, Barracuda, Silver Jenny, and Silver Perch (Frazer et al. 2011); Black Crappie and Scaled Sardine (Johnson et al. 2017).

Herald and Strickland (1949) described general physical and chemical characteristics of the main springs surrounding the fish bowl. They note a combination of fresh and saltwater species. The authors report first and second-hand sightings of species, as well as data from other sources, for example, a mounted sturgeon on the wall of the Old Mill Tavern, which is said to have been taken from the river “about ten years ago.”

Wetland Solutions, Inc. (2010) conducted visual surveys of fish presence. They compared findings at 12 springs, including the Homosassa Main Spring and its run. Homosassa Springs had the most marine species with 16/22 total species.

Frazer et al. (2011) conducted electrofishing and seining for three days each during four periods (summer 2007, winter 2008, summer 2008, and winter 2009). They found higher densities of fish upstream near the springs. They compared abundance in the Homosassa and Chassahowitzka river systems. The Homosassa River had lower densities of Largemouth Bass, *Lepomis* spp., and Lake Chubsucker, and higher density of Florida Gar (*Lepisosteus platyrhincus*).

Peebles et al. (2009) surveyed with plankton nets, seines, and trawls. Plankton net surveys conducted at night found both zooplankton – weakly swimming fish and invertebrates suspended in the water column, and hyperbenthos – animals associated with the bottom but suspended above it. Sampling began in December 2006, continued monthly for one year and every other month for a second year, resulting in 18 collections through November 2008. An effort was made to sample throughout the river from the head springs to the mouth, but plankton net tows were not made in the upper Halls River due to shallow depths, and trawls were not made in several locations due to obstructions. Seine halls were made throughout the system.

Larval gobies and anchovies dominated the plankton net fish catch of Peebles et al. (2009). The seine catch was dominated by rainwater killifish (*Lucania parva*), menidia silversides (*Menidia* spp.) and eucinostomus mojarras (*Eucinostomus* spp.), which accounted for greater than seventy percent of the catch. Rainwater Killifish prefer habitat with submerged aquatic vegetation (Jordan 2002) and are important food for larger fish (Hettler 1989) in Florida estuaries. Menidia silversides migrate between higher and lower salinity areas of estuaries, underscoring the importance of maintaining a natural salinity regime (Lucas 1982).

Trawls found mojarra less than 40mm (*Eucinostomus* spp.), rainwater killifish (*L. parva*), bay anchovy (*Anchoa mitchilli*) and tidewater mojarra (*E. harengulus*) greater than 40 mm in length (Peebles et al. 2009). These four taxa represented 77% of the total trawl catch of fishes.

The plankton-net invertebrate catch reported by Peebles et al. (2009) was dominated by larval crabs (decapod zoeae and megalopae), larval shrimps (decapod mysis), gammaridean amphipods, the mysid *Americamysis almyra*, cumaceans, and the copepod *Acartia tonsa*. The authors state that *Americamysis almyra* and *Acartia tonsa* are usually associated with surface-fed estuaries and may be indicators of eutrophication in the Homosassa River. The gammaridean amphipods were abundant throughout most of the survey area, being somewhat less abundant near the Gulf of Mexico. In contrast, cumaceans were most abundant downstream, which is a commonly observed pattern in other estuaries. The larval crabs, larval shrimps, the mysid *Americamysis almyra* and the copepod *Acartia tonsa*, were all widely distributed throughout the survey area.

Taxon richness in the nearshore area was low from January to April, increased in May, was particularly high from June to July and in October, and remained elevated until December (Peebles et al. 2009). Among the 64 plankton-net taxa evaluated for distribution relationships with freshwater inflow, 42% (n = 27) exhibited significant responses. Eleven taxa moved downstream with increasing flow, and 16 moved upstream. Over 24% (n=13) of the 53 pseudo-species evaluated for distributional responses to freshwater inflow exhibited significant response for at least one lagged flow period.

Among the 64 plankton-net taxa evaluated for abundance relationships with freshwater inflow, 44% (n = 28) exhibited significant responses. All except five of these were negative responses. Negative responses are usually caused by elevated flows washing organisms out of the survey area. The organisms that had positive responses were the estuarine tanaid *Hargeria rapax*, postflexion larvae of the oligohaline Rainwater Killifish (*Lucania parva*), freshwater podocopid ostracods, the estuarine copepod *Acartia tonsa*, and the oligohaline copepod *Eurytemora affinis*. It could be concluded that more positive results were not observed because no stations were positioned in the Gulf of Mexico to account for species that moved downstream and increased in number in response to increased inflow. Seine and trawl net abundance responses to flow are complex, many non-linear relationships are significant. 27 linear relationships were found, 12 of which showed decreased abundance with increased flow, and 15 showed increased abundance and flow.

Peebles et al. (2009) organized the Homosassa River into seven sampling zones. They found each zone has a unique assemblage of species as detected by plankton net, seine, and trawl catches. Estuary-dependent taxa spawned outside the Homosassa River estuary that use the study area as a nursery were prevalent in the samples. These included numerically abundant taxa that undoubtedly play a vital ecological role in the Homosassa River System (i.e., Pinfish and juvenile mojarras). Also prominent were taxa of recreational and commercial importance, including juvenile Blue Crab and Pink Shrimp.

Table 4-9. Sources of historical fish data for the Homosassa River and number of species identified (richness) from Johnson et al. (2017). All sources cited in Johnson et al. (2017).

Citation	Years	Richness
Herald and Strickland (1949)	1949	32
FMNH	1953	5
FMNH	2001-2002	20
Walsh and Williams (2003)	2003	33
Frazer et al. (2011)	2007-2010	48
Wetland Solutions, Inc. (2010)	2010	23
Pine (2011)	2008-2011	19
Johnson et al. (2017)	2013-2017	53

4.4 Manatee Status and Habitat Definition

The Florida manatee, *Trichechus manatus latirostris*, is a subspecies of the West Indian manatee and is a high profile, threatened species whose geographic range is restricted to the southeastern U.S. (predominantly Florida) because of its limited tolerance to cold temperatures (< 20°C) (Bossart et al. 2002, Laist and Reynolds 2005, Laist et al. 2013). Due to population declines associated with hunting pressures during the 1500s to 1800s, the Florida manatee was designated as an endangered species under the Endangered Species Act; however, owing to the partial recovery of the manatee's population, this subspecies was recently downlisted from endangered to threatened (USFWS 2017). Part of the manatee's successful population increase is a result of protection of their habitat, boating restrictions, and limitations on human interactions with the animals, which are all set forth by the Florida Manatee Sanctuary Act (as implemented in Rule 68C-22, F.A.C). As of 2018, synoptic aerial surveys estimate a minimum of 6,131 manatees in the waters of Florida of which a minimum of 2,400 are found along Florida's west coast. Aerial surveys of manatees in the Homosassa River conducted from 2011 to 2018 have identified a maximum of 281 manatee (Joyce Kleen, personal communication) (Table 4-10). Although their populations are rebounding, manatees are still highly susceptible to die-offs associated with watercraft, water control structures, marine debris, red tide, cold stress, and other factors (Runge et al. 2017).

Because manatees have low metabolic rates and consume a relatively poor quality food source (Irvine 1983), they must seek out warm water refuges when air temperatures begin to drop (Bossart et al. 2002). In Florida, these warmer waters primarily consist of discharge from natural springs, discharge from power plants, and/or passive thermal basins (Laist et al. 2013). Based on synoptic aerial counts during winter months, Laist et al. (2013) estimate that 88.6% of the state's subpopulation of manatees seeking refuge in Northwest Florida rely on warmer waters being discharged from springs. For example, during the record low temperatures in 2010, a minimum of 645 manatees were observed in that coastal area. In addition to providing thermal refugia, freshwater discharge from artesian springs is positively correlated with the development of stratified salinity differences (haloclines) in water bodies, and such stratification can be important because it might also lead to the formation of temperature inversions (Stith et al. 2011). These temperature inverted haloclines can create passive thermal refugia (PTR) where a bottom layer of warm, salty water forms and can be sought out by manatees (Stith et al. 2011). Stith et al. (2011) also indicate that reduced freshwater discharge is strongly associated with the loss of these haloclines, and subsequently, a loss of the PTRs. Furthermore, as power plants (warm effluent utilized by 48.5% of all of Florida's manatees) are retired, a large amount of these subpopulations will likely have to begin relying on the warmer waters that are associated with springs (Laist et al. 2013). Based on these direct and indirect thermal benefits of spring discharge, it is imperative that that an appropriate discharge be maintained to support growing manatee populations.

When manatees are exposed to prolonged cold temperatures (< 20°C for several days), they experience cold stress syndrome (CSS) which can ultimately result in death; CSS is caused by nutritional, metabolic, and/or immunological disturbances that often result diseases caused by opportunistic pathogens (Bossart et al. 2002). Reported and confirmed manatee death data indicate that from 1974-2018, 8.9% of the 12,114 deaths was cold stress-induced (Figure 2) (FWC 2018). This number is likely to be underestimated because approximately 27% of the deaths reported by FWC are labeled as 'undetermined' (Figure 4-24) which may also be linked to cold stress; of the 'undetermined' deaths, approximately 50% occurred during the typical cold months (November - March). During the three largest cold stress die-offs in 2010, 2011, and 2018 (Figure 4-25), only 6 manatees were reported to have died due to cold stress in the Citrus County area; this indicates that manatees along the Citrus County coast are less likely to die from cold stress than at other Florida locations. This unusually low death rate from cold stress is kept low because of the springs feeding the Crystal River/Kings Bay, Homosassa River, and Chassahowitzka River systems, all of which are located in Citrus County. These low mortality rates are further reverberated by Laist et al. (2013), who concluded that relative to power plant discharge and natural passive thermal refugia, springs offer the best source of protection against cold stress. It should be noted that available data on manatee deaths in 2017 and 2018 are preliminary and reflect conditions only through August 2018. Furthermore, in some years, cold stress mortality counts were combined with natural mortality counts, which could also underestimate the cold stress deaths.

For the reevaluation of minimum flows for the Homosassa River System and previous minimum flow assessments for several District rivers, thermal criteria were established for the Florida manatee based on Rouhani et al. (2007). For the Homosassa River reevaluation, we defined adequate thermal refuge based on chronic and acute cold stress conditions. To meet adequate thermal habitat for chronic conditions, the water must not be ≤ 20°C for > 3 days; for acute conditions, the water must not be ≤ 15°C for > 4 hrs. Additionally, we estimate that each manatee requires an area of 28.5 square feet and a total volume of 108 cubic feet with a minimum water depth of 3.8 feet (Figure 4-26). These space requirements were originally adopted for Blue Spring with the St. Johns Water Management District, but they used a minimum depth of 5 ft (Rouhani et al. 2007). These criteria, including the minimum depth of 3.8 feet, were used for prior minimum flows analyses completed for the Chassahowitzka River, Homosassa River, Weeki Wachee River, and Crystal River / Kings Bay systems.

Table 4-10. Manatee aerial survey counts for the Homosassa River System from the U.S. Fish and Wildlife Service (Joyce Kleen, personal communication).

Year	Maximum Count
2011	101
2012	89
2013	183
2014	134
2015	268
2016	281
2017	200
2018	118

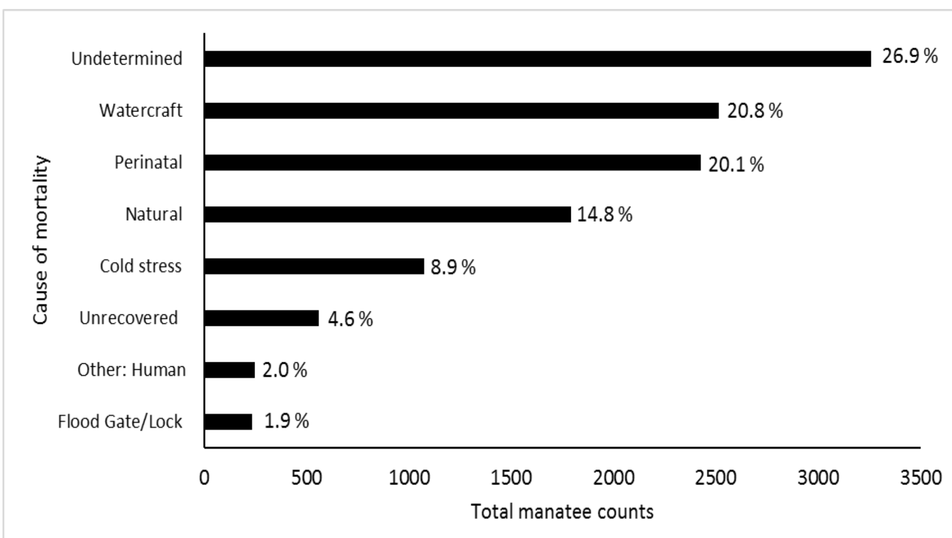


Figure 4-24. Total manatee deaths in Florida by category from 1974-2018 (from FWC 2018). Percentages indicate categorical contribution to overall reported deaths.

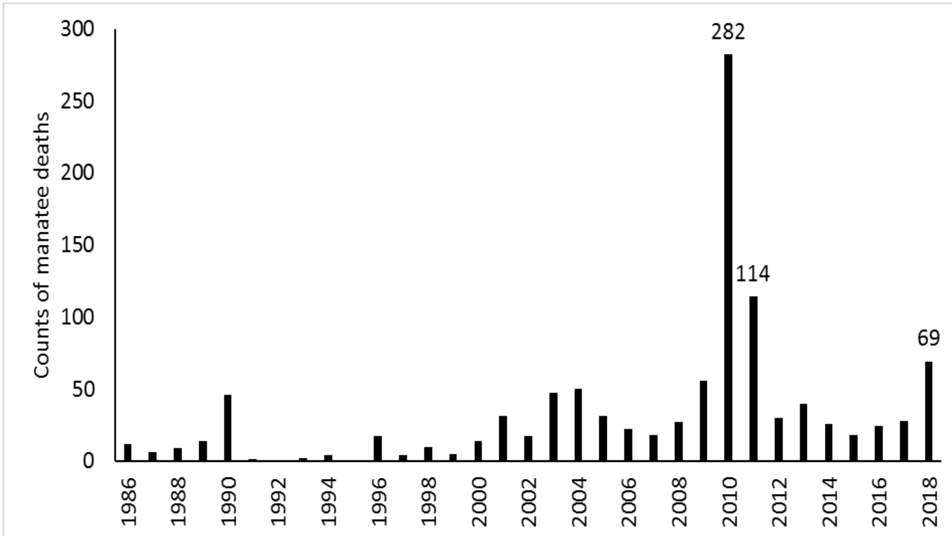


Figure 4-25. Counts of manatee deaths due to cold stress from 1974-2018 (from FWC 2018). No reports of cold stress-induced deaths were reported prior to 1986. According to data accessed within the FWC database at the time of analyses for this report, the 2017 and 2018 data were considered to be preliminary.

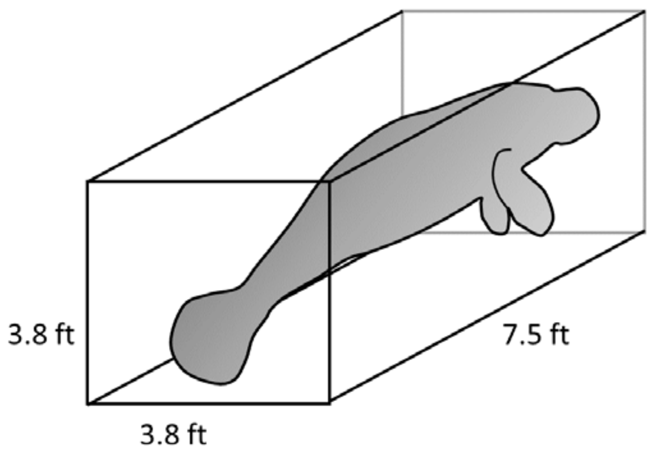


Figure 4-26. Dimensional criteria adopted for suitable manatee thermal space during cold stress events. Manatee space requirements are reproduced from Rouhani et al. (2007).

4.5 <u>Common Snook Habitat</u>

Common Snook (*Centropomus undecimalis*) is one of Florida's most popular gamefish and were the third most commonly targeted gamefish on the Florida Gulf Coast in 2014 (Muller et al. 2015). Common Snook were the third most abundant fish caught in the Homosassa River from December 2013 to May 2018, constituting 8.6 percent of the total catch (Figure 4-20) (Johnson et al. 2017). Snook become more abundant in the winter than summer, consistent with their use of this habitat as warm water refuge. Studies of Common Snook have demonstrated temperature-based habitat requirements associated with a 10-15°C threshold. The geographical distribution of Common Snook is restricted by temperature with their northern range limited by the 15°C winter isotherm (Adams et al. 2012, Blewett and Stevens 2014); they stop feeding completely at 14.2(+/-2.1)°C, lose equilibrium at 12.7°C, and die at 12.5°C (Shafland and Foote 1983). However, some populations of Common Snook may be less sensitive to temperature (Howells et al. 1990).

Cold events in winters, and particularly in winter 2010, had negative impacts on Common Snook populations along the south-western coast of Florida. Common Snook in this region of Florida are located at the northern extent of their geographical distribution and can experience thermal stress when water temperatures decline in winter months (Muller et al. 2015). Lethal effects of cold were responsible for decline in Common Snook populations in the region following winter 2010 (Adams et al. 2012; Stevens et al. 2016). As a result of mortality caused by cold stress in 2010, the Common Snook fishery was closed in the Gulf from 2010 to 2013 (Muller et al. 2015). Common Snook responded differently in different estuaries in Florida (Stevens et al. 2016), underlying the importance of spring-fed estuaries that provide consistent temperature refuge from cold waters in the Gulf of Mexico. Unlike the Florida Manatee, Common Snook appear to have no upper limit to their useable winter warm-water habitat. Common Snook have the ability to recognize relatively short-term changes in weather patterns and seek warm water habitat. Therefore, reductions in the volume and area of water greater than 15°C has the potential to adversely impact Common Snook populations. Electrofishing surveys and seine-haul data from the Charlotte Harbor area suggest that Common Snook may move to sites that are warmer or more stable during cold fronts (Blewett et al. 2009). At a broader scale, hydrology and temperature drive seasonal patterns of river use by the species along a latitudinal gradient (Stevens et al. 2018). In rivers of southwestern Florida (those in Everglades and Charlotte Harbor), Common Snook abundances increased three-fold during the time of year when surface waters inundating floodplains recede and force prey into the main stems of rivers. In spring-fed rivers north of Tampa Bay, Common Snook abundances generally double during winter compared to those of summer; stable water temperatures are thought to provide thermal refuge at the northernmost range of the species. Therefore, it should be expected that reductions in the volume and area of these warmer aquatic habitats (i.e., springs and spring-fed rivers/streams) has the potential to adversely impact Common Snook populations.

Common Snook seem to be more abundant in winter than in summer in the Homosassa River (Figure 4-20).

CHAPTER 5 - HYDROLOGIC EVALUATION OF THE HOMOSASSA RIVER WATERSHED

This chapter provides a description of the Homosassa River watershed, Homosassa springshed, and surrounding area that includes information on the geology, hydrology, rainfall, water use, springflow, and groundwater withdrawal impacts to the Homosassa River System. Prior to the development of a minimum flow, the District evaluates hydrologic changes in the vicinity of the system and determines the impact on flow from existing groundwater withdrawals.

5.1 <u>Hydrologic Setting</u>

The Homosassa River watershed boundary is delineated by the USGS (see Figures 2-3 and 2-13). It is important to note that much of the watershed is internally-drained – so while the surface water runoff contributing area has been identified – there is very little runoff that actually occurs to the Homosassa River. It is primarily a baseflow-dominated or spring-fed system.

The groundwater contributing area to the Homosassa Springs Group is named a springshed. The springshed covers an area of about 261 square miles in northern Hernando and southern Citrus Counties (Figure 5-1). Springsheds are generally based on the groundwater flow field of the Upper Floridan aquifer (UFA). They may change slightly from year to year based on the measured elevation of the water levels within the UFA and availability of measured water level data. However, for the most part, they are semi-permanent areas that contribute flow to a spring.

The land area within the Homosassa Springshed has high rolling sand hills with pine and hardwood forest, pastureland, and developed areas. The hydrogeologic framework in this area includes a surficial aquifer, a discontinuous intermediate confining unit, and a thick carbonate UFA. At land surface and extending several tens of feet deep are generally fine-grained quartz sands that grade into clayey sand just above the contact with limestone. A thin, sometimes absent, sandy clay layer forms the intermediate confining unit (ICU) and overlies the limestone units of the UFA. In general, a regionally extensive surficial aquifer is not present because the clay confining unit is thin, discontinuous, and breeched by numerous karst features (Figure 5-2). Because of this geology, the UFA is unconfined over most of the northern Hernando and southern Citrus county area. In this unconfined setting, high infiltration soils and generally deep-water table conditions exist with UFA water levels varying from 10 to more than 50 feet below land surface except west of US 19 near the coast or near the Withlacoochee River to the east (Figure 5-3).

The geologic units, in descending order, that form the freshwater portion of the UFA include the upper Eocene age Ocala Limestone and the middle Eocene age Avon Park Formation (Table 5-1). In northern Hernando and southern Citrus counties, the Ocala Limestone forms the top of the UFA. The entire carbonate sequence of the UFA thickens and dips toward the south and southwest. The average thickness of the UFA ranges from 500 feet in southwest Marion County to 1,000 feet in central Pasco County (Miller 1986).

The base of the UFA generally occurs at the first, persistent sequence of evaporitic minerals such as gypsum or anhydrite that occur as nodules or discontinuous thin layers in the carbonate matrix. This low permeability unit is regionally extensive and is generally referred to as Middle Confining

Unit (MCU) 2 (Miller 1986). The sub-Floridan confining unit forms the bottom of the Floridan aquifer system and is found in the top part of the Cedar Keys Formation at an elevation of -1,700 feet NGVD29 (FGS 2009).

The Homosassa springshed is located within the 4,600 square mile Northern West-Central Florida Groundwater Basin (SWFWMD 1987), which is one of seven regional groundwater basins located on the Florida peninsula (Figure 5-4). Similar to topographic divides that separate surface water drainage basins, groundwater basins are delineated by divides formed by high and low elevations in groundwater levels. Groundwater does not flow laterally between basins. Each basin also generally contains similar geology regarding the confinement of the UFA. In well-confined basins, water level declines due to pumping are greatest and most widespread. In leaky or unconfined basins, regional pumping impacts are confined to within each basin or along their boundaries. These effects are more localized and near major pumping centers due to leakage from the overlying surficial aquifer or high storage within the UFA. This limits regional pumping impacts. This can be seen in the UFA water level change from 1970 to 2010 from the USGS (Figure 5-5). The greatest lowering of water levels in the UFA occurs in well-confined areas of southeast Georgia, Northeast Florida, and Southwest Florida, where there is large groundwater extraction (Williams et al. 2011). In the unconfined regions, water level changes are small. Changes in UFA water levels largely occur due to rainfall variation. In this region, pumping impacts are more localized and groundwater extraction is low.

In the Homosassa springshed, the UFA is regionally unconfined and is located within a highly karst-dominated region. Dissolution of limestone is an active process via infiltration of rainwater because the limestone units of the UFA are close to land surface and poorly confined. Numerous sinkholes, internal drainage, and undulating topography that is typical of karst geology dominates the landscape. These active karst processes lead to enhanced permeability within the Floridan aquifer. The mean transmissivity value of the UFA based on seven aquifer performance tests in Citrus, Levy, and western Marion Counties is 1,070,000 $feet^2$/day (SWFWMD 1999). There are five additional first-magnitude springs (flow greater than 100 cfs discharge) found within the Northern West-Central Florida Groundwater Basin: the Kings Bay group, Chassahowitzka group, Rainbow group, Weeki Wachee group, and Silver Springs. In addition, the highest recharge rates to the UFA in the state occur in West-Central Hernando and Citrus Counties with values ranging between 10 and 25 inches per year (Sepulveda 2002).

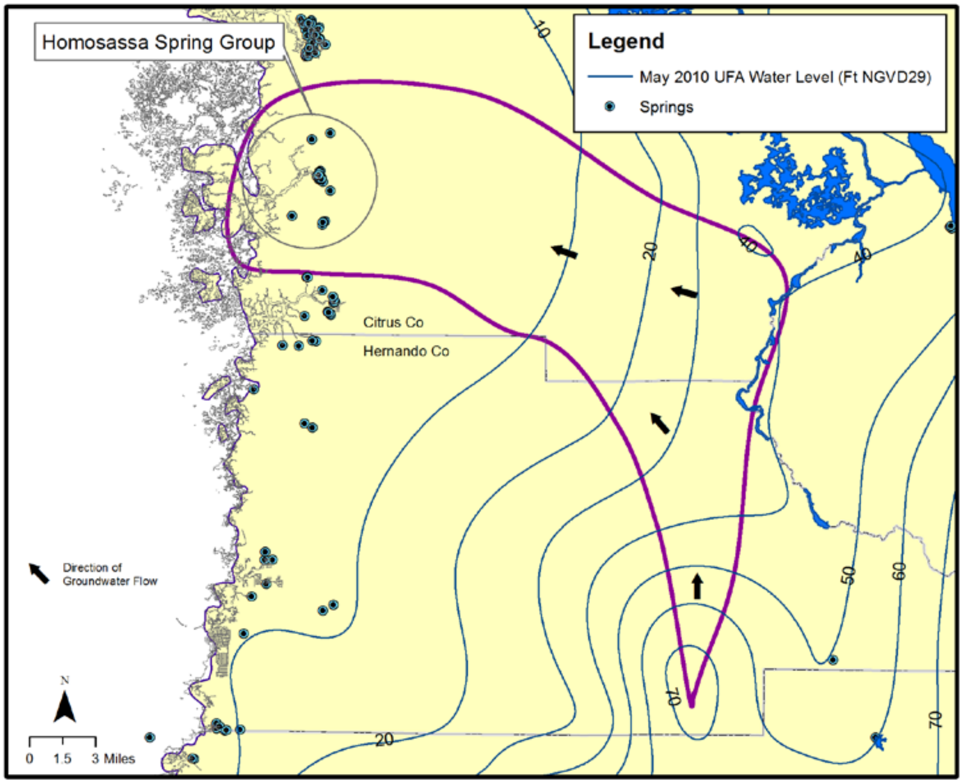


Figure 5-1. Location of Homosassa springshed.

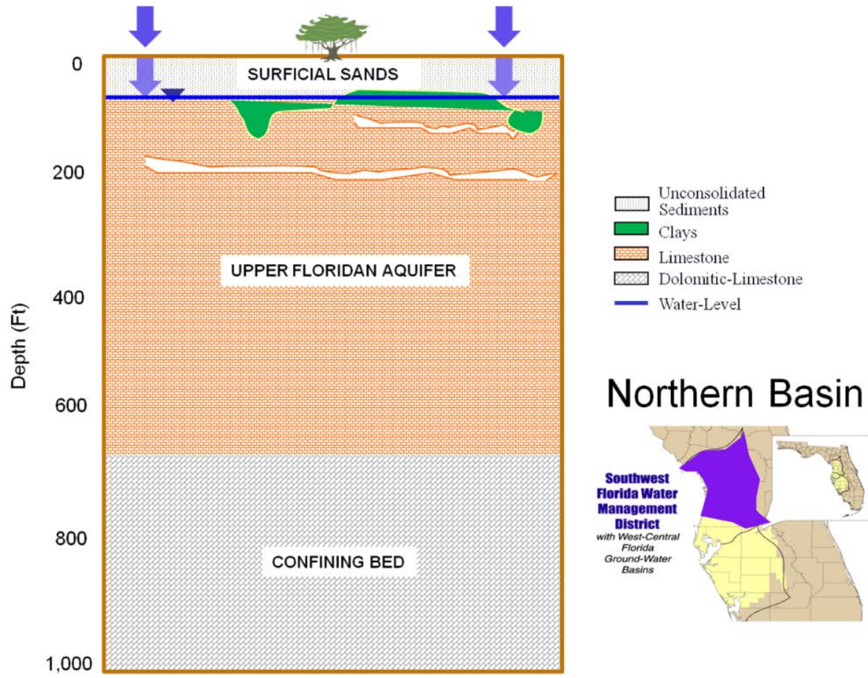


Figure 5-2. Generalized hydrogeology within the Homosassa springshed.

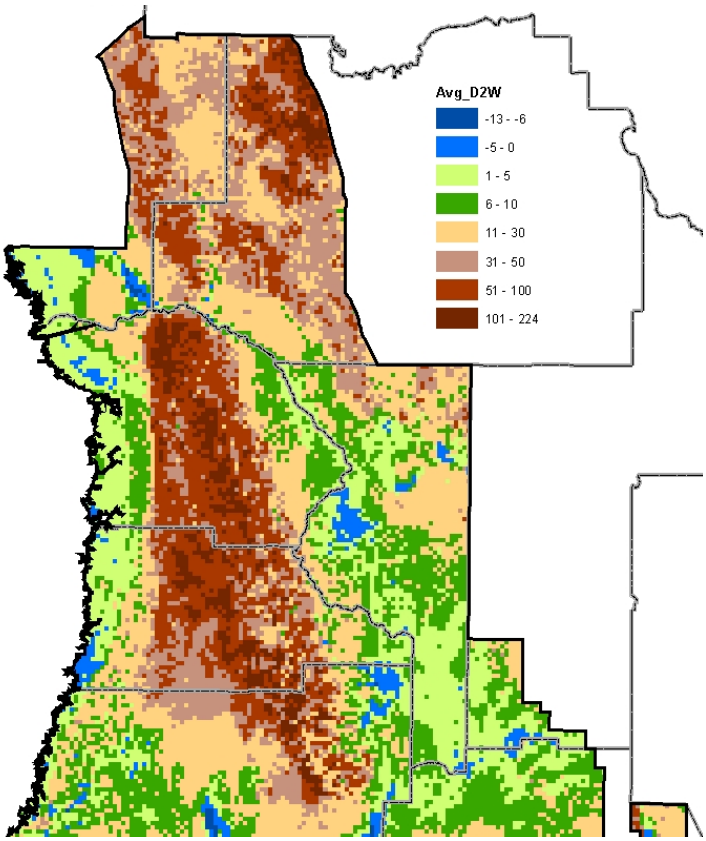


Figure 5-3. Depth below land surface (feet) to the water level in the Upper Floridan aquifer based on the average of May and September U.S. Geological Survey potentiometric surface maps (average 2002 conditions).

Table 5-1. Hydrogeology of the Homosassa Springs area (modified from Miller 1986, Sacks and Tihansky 1996).

<table>
<tr><th>Series</th><th>Stratigraphic Unit</th><th colspan="2">Hydrogeologic Unit</th><th>Lithology</th></tr>
<tr><td>Holocene to Pliocene</td><td>Undifferentiated Surficial Deposits</td><td colspan="2">Unsaturated Zone, Surficial Aquifer or locally perched Surficial Aquifer</td><td>Sand, silty sand, clayey sand, sandy clay, peat, and shell</td></tr>
<tr><td rowspan="5">Eocene</td><td>Ocala Limestone</td><td rowspan="2">Upper Permeable Zone</td><td rowspan="2">Upper Floridan Aquifer</td><td rowspan="2">Limestone, white to tan, friable to micritic, fine-grained, soft, abundant foraminifera</td></tr>
<tr><td rowspan="3">Avon Park Formation</td></tr>
<tr><td colspan="2">Middle Confining Unit 2</td><td>Dolomite is brown, fractured, sucrosic, hard. Interstitial gypsum in Middle Confining Unit 2</td></tr>
<tr><td rowspan="2">Lower Permeable Zone</td><td rowspan="2">Lower Floridan Aquifer</td><td rowspan="2">Limestone and dolomite. Limestone is tan, recrystallized. Anhydrite and gypsum inclusions.</td></tr>
<tr><td>Oldsmar Formation</td></tr>
<tr><td>Paleocene</td><td>Cedar Keys Formation</td><td colspan="2">Basal Confining Unit</td><td>Massive anhydrites</td></tr>
</table>

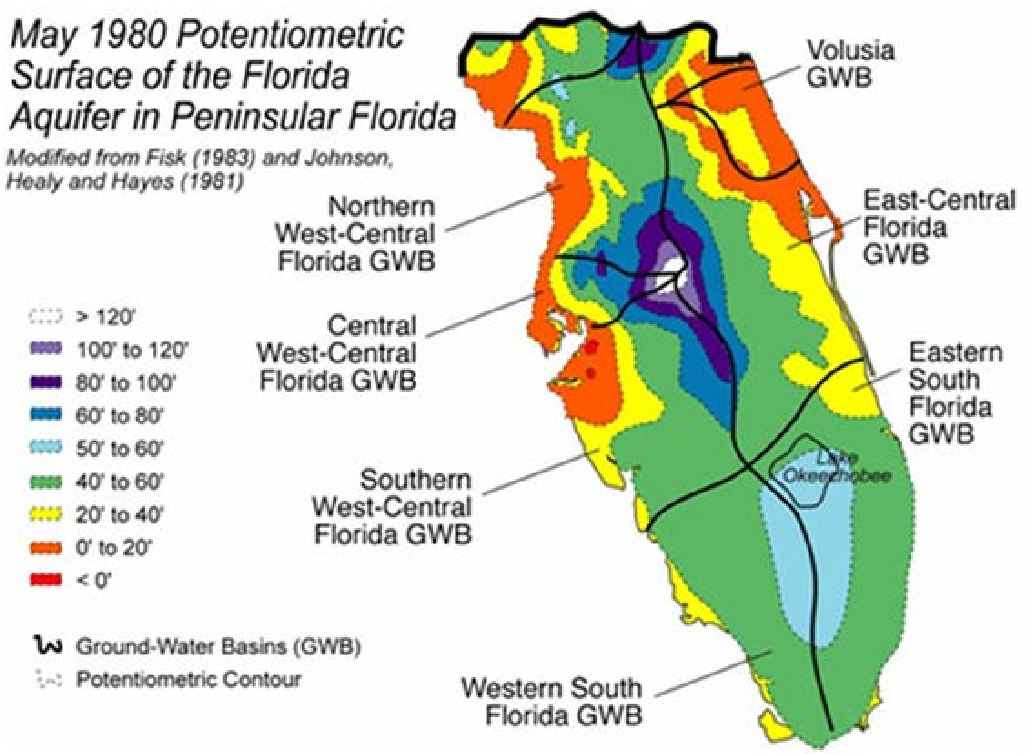
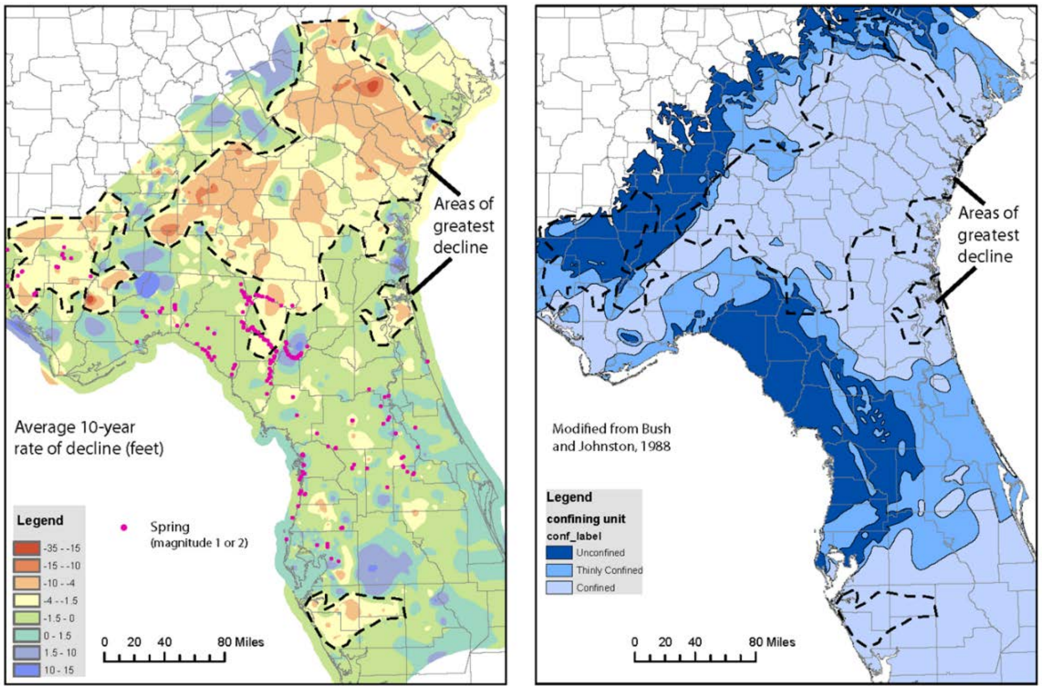


Figure 5-4. Location of regional groundwater basins in the Upper Floridan aquifer.



A. Composite 10-year rate of decline map for 1970 to 2010. Reds and yellows indicate declining trends; blues indicate increasing trends; greens indicates slightly increasing or decreasing trends in water levels.

B. Relative confinment of the Floridan Aquifer System Light blue indicates confined areas and darker blues indicate thinly confined and unconfined areas respectively.

Figure 5-5. Water level change in the Upper Floridan aquifer from 1970 through 2010 and the degree of confinement for the Upper Floridan aquifer (from Williams et al. 2011).

5.2 Climate and Rainfall

The Homosassa springshed lies within a humid subtropical zone that is influenced by its proximity to the Gulf of Mexico. Subtropical zones are characterized by hot, humid summers and mild to cool winters. The temperature of the Gulf waters moderates the air temperatures in the area. The average mean daily temperature is approximately 70° F (21° C). Mean summer temperatures are in the low 80s (°F) and the mean winter temperatures are in the upper 50s (°F).

Average rainfall is approximately 54 inches per year but varies widely from season to season and year to year. About 60 percent of annual rainfall occurs in the summer rainy season months of June through September when convective thunderstorms are common due to daytime heating and afternoon sea breezes. In addition, summer and fall rainfall can be enhanced by tropical cyclone activity from June through November. An analysis of median decadal rainfall and 20-year moving average rainfall accumulated from the Ocala, Inverness, and Brooksville National Weather Service (NWS) stations from 1901 through 2017 shows an increasing trend up until the mid-1960s and then a declining trend thereafter (Figures 5-6 and 5-7). This is consistent with multi-decadal cycles associated with the Atlantic Multidecadal Oscillation (AMO) (Enfield et al. 2001, Kelly and Gore 2008, Cameron et al., 2018). The 20-year average was below the bottom 10^{th} percentile (P90) for most of the averages post-2000 (Figure 5-7). Recent 20-year periods (1996-2015, 1997-2016, and 1998-2017) have increased and lie between the P90 and P50 percentiles.

The departure in annual rainfall from the mean shows that 21 out of 29 years since 1989 have recorded below average rainfall (Figure 5-8). Therefore, the recent quarter century has been extremely dry; it is the driest in 117 years of recorded rainfall history as averaged from these three stations. Over the last six years since 2012, however, rainfall has been near average to slightly above average (54.9 in/yr averaged from the three stations).

Much of the lower rainfall experienced over the last 25 years is related to below average landfalling hurricanes and reductions in dry season rainfall associated with increasing La Niña events (Cameron et al. 2018). The state of Florida saw 11 consecutive years – from 2005 (Wilma) until 2016 (Hermine) – without a single landfalling hurricane. This represents the longest hurricane drought for the state in more than 150 years. Cameron et al. (2018) also found that an increase in La Niña duration and a simultaneous decrease in El Niño events has led to lower dry season rainfall at most stations in the District. In the northern portion of the District, these ENSO-driven dry season decreases have completely cancelled out AMO-related wet season increases – such that the current warm phase has experienced lower annual rainfall than the preceding cool phase. This reduced dry season rainfall in the northern District largely explains more recent low aquifer water levels, river, and spring flows that haven't recovered to those of the preceding warm AMO period prior to 1970.

In addition to the rainfall recorded at Brooksville, Inverness, and Ocala stations, radar-estimated rainfall became available to the District in 1995 at a 2-kilometer (km) grid scale. Radar-estimated rainfall was averaged for the entire springshed each year from 1995 through 2017 using the 261 square-mile May 2010 springshed boundary (Figure 5-9). Similar to the NWS station data, 16 out of 23 years of radar estimated rainfall were below average since 1995 (Basso 2019a [Appendix 4]). The cumulative departure from the mean rainfall for the 23-year period was -37.6 inches.

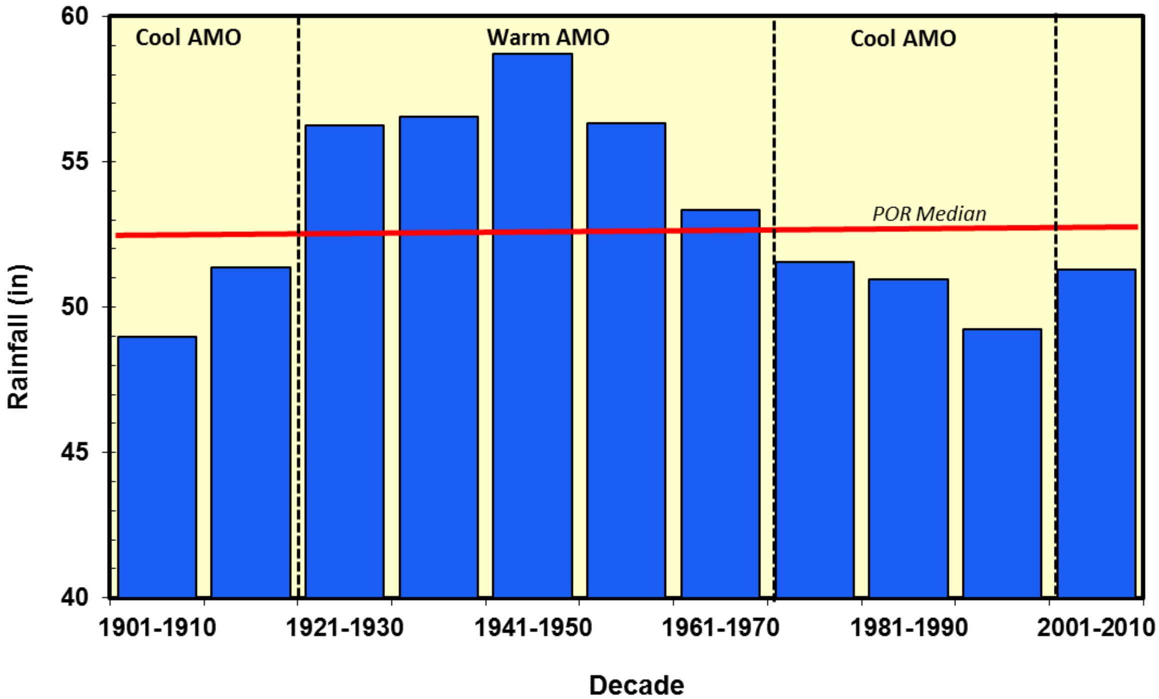


Figure 5-6. Atlantic Multidecadal Oscillation (AMO) periods and median decadal rainfall from the Brooksville, Inverness, and Ocala National Weather Service stations from 1901 through 2010.

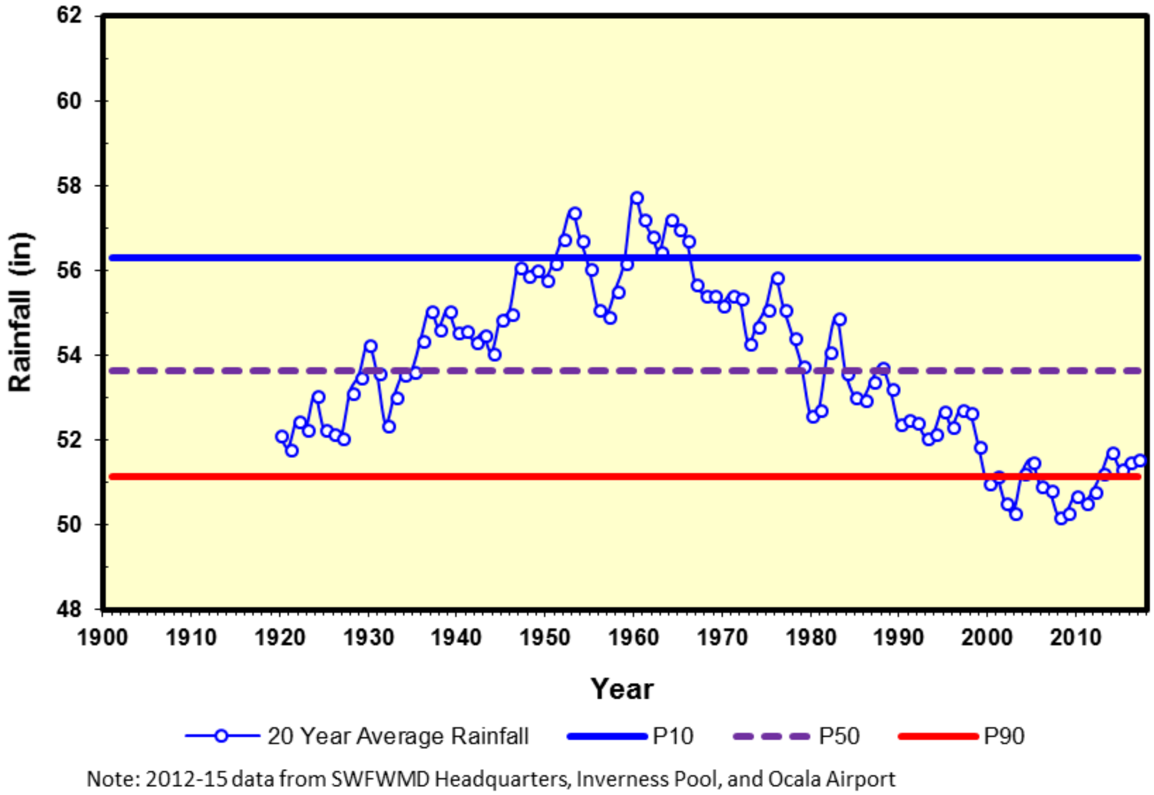
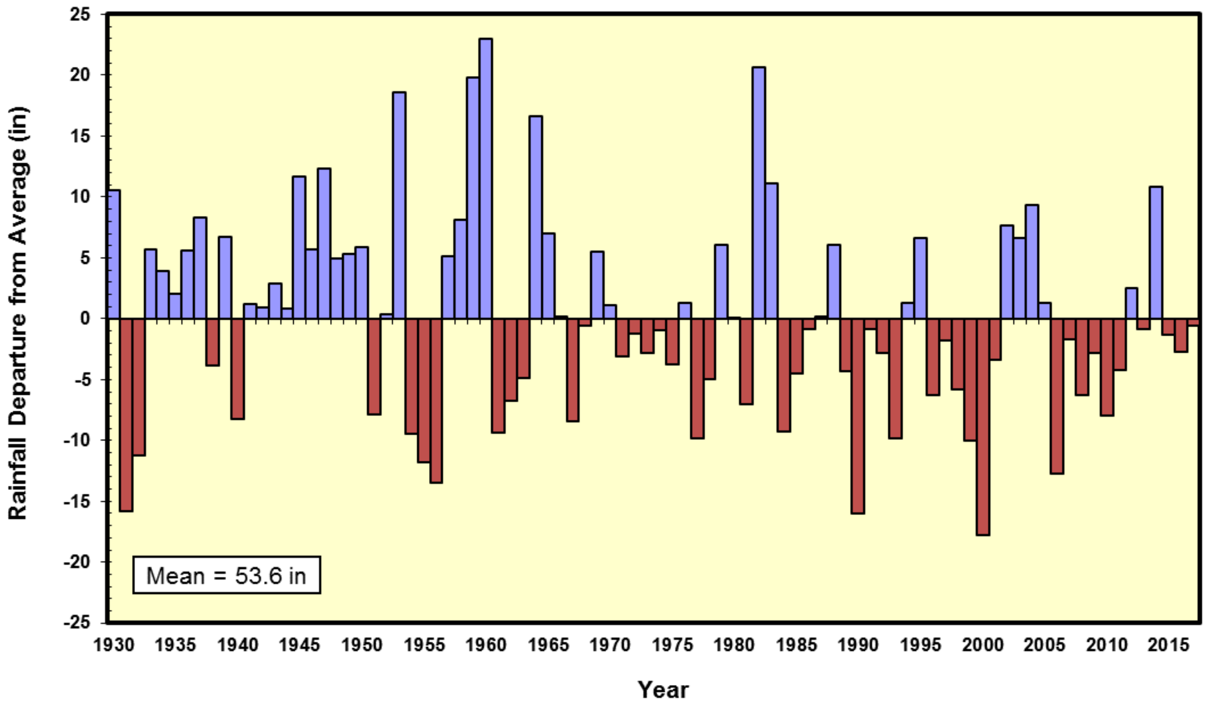


Figure 5-7. Twenty-year moving average rainfall from the Brooksville, Inverness, and Ocala National Weather Service stations from 1901 through 2017.



Note: 2012-15 data from SWFWMD Headquarters, Inverness Pool, and Ocala Airport

Figure 5-8. Departure in annual rainfall from the Brooksville, Inverness, and Ocala National Weather Service stations from 1930 through 2017.

5.3 Homosassa No. 1 Spring Discharge and Upper Floridan Aquifer Water Levels

The Homosassa River and springs system is located in southwest Citrus County within the District. A large spring and numerous smaller springs provide flow to the Homosassa River, which winds through nearly six miles of lowland swamps and discharges into the Gulf of Mexico (Cherry and others,1970). Freshwater flow to the Homosassa River is the result of discharge from Homosassa Springs, springs supplying flow to the Southeast Fork of the Homosassa River, and springs supplying flow to Halls River (Knochenmus and Yobbi, 2001). These springs collectively are herein referred to as the Homosassa Spring group.

The Homosassa Spring Group consists of a collection of springs that discharge to the Homosassa River or its tributaries and Hidden River. It includes Homosassa No. 1, Halls River Head, Halls River No. 1, Abdoney, Belcher, McClain, Pumphouse, Trotter, and Hidden River head springs. All the springs are tidally influenced. Homosassa No. 1 Spring discharge is gaged at USGS Homosassa Springs at Homosassa Springs, FL (No. 02310678) (Figure 5-10). From October 1995 to August 2018, mean spring discharge was 87.8 cubic feet per second (cfs) or 56.7 mgd. This site includes flow from the main vents and several smaller springs. Prior to this date, there were only infrequent measurements of discharge from the spring. In addition to Homosassa 1, discharge has been recorded at the SE Folk of the Homosassa River, Hidden River, and downstream of where the Halls River enters the Homosassa River by the USGS. Mean daily discharge of the Homosassa River at Homosassa FL (USGS No.02310700) using tidally-filtered data from the USGS was 228 cfs from 2004 through 2018 (Figure 5-11).

The Homosassa No. 1 Spring discharge has been continuously recorded by the USGS (Figure 5-10) from the Homosassa Springs at Homosassa Springs, FL Gage (No. 02310678). Continuous daily flow observations based on a regression equation were initiated in late 1995. The USGS has used rating curve relations between water levels in the Weeki Wachee FLDN REPL Well near Weeki Wachee, FL (No. 283154082313701) and measured flow on the Homosassa River to calculate continuous flow at 15-minute intervals at this station. Index velocity flow measurements, a newer method of measuring flow, was initiated in 2012 by the USGS at this station.

The Lecanto 2 well (WMIS Site No. 21039; USGS No. 284339082270402), which monitors water levels within the UFA, is located about 9.5 miles southeast of the Homosassa No. 1 spring vent. Data from this well was first recorded in late 1965, and its water level history is shown in Figure 5-12. This monitor well has the longest period-of-record within the Homosassa springshed. A review of closer monitor wells to the spring group such as Homosassa No. 3 (WMIS Site No. 21049; USGS No. 284551082345301) and Homosassa No. 1 (WMIS Site No. 21052; USGS No. 284532082371001) indicate a shorter monitoring period and large multi-year gaps in measurements. Aquifer water levels at the Lecanto 2 well have generally fluctuated between 5 and 15 feet NGVD29 over the last 50 years. Simple linear regression of the daily Lecanto 2 well water levels since 1965 shows a statistically significant downward trend ($p \leq 0.05$) of about 1.8 feet for the period September 1965 through July 2018 (Figure 5-13). However, applying linear regression to the daily water levels from January 1990 through July 2018 indicates slightly rising water levels that are not statistically significant. Table 5-2 shows linear water level trends since 1965 and 1990 and their significance levels. Based on this analysis, much of the long-term water level decline at this well occurred prior to 1990. This decline was due predominately to higher rainfall during the pre-1990 period compared to the last 25 years.

In addition to the Lecanto 2 well, other long-term monitor well water levels were examined within or adjacent to the springshed that had data back to at least 1990. Individual well hydrographs since 1990 are shown in Figure 5-14 for seven wells in the Homosassa and adjacent Chassahowitzka springsheds. Linear regression of the seven Upper Floridan aquifer monitor well water levels from 1990 through July 2018 showed that six of seven had increasing trends varying from 0.1 to 1 foot (Figure 5-15). Four of the six were statistically significant (Table 5-3). One well, the Romp 109 UFA well displayed a slight downward trend of 0.22 ft that was statistically significant. This data is generally consistent with water level trends evidenced in the Lecanto 2 well over the last nearly three decades – that water levels vary from year to year due to annual variation in rainfall, but the overall trend is generally flat since the early-1990s.

5.3.1 Rainfall and Upper Floridan Water Levels

A cumulative sum analysis of annual rainfall averaged from the Brooksville, Inverness, and Ocala NWS stations and average annual water levels at the Lecanto 2 well from 1965 through 2017 indicates no significant change in slope for the period (Figures 5-16 and 5-17). In the cumulative sum analysis, any major deviation in slope that occurs for more than five years would indicate an influence other than rainfall affecting water levels in the well. This suggests that water levels in the UFA are fluctuating largely due to the natural variability of rainfall in the area.

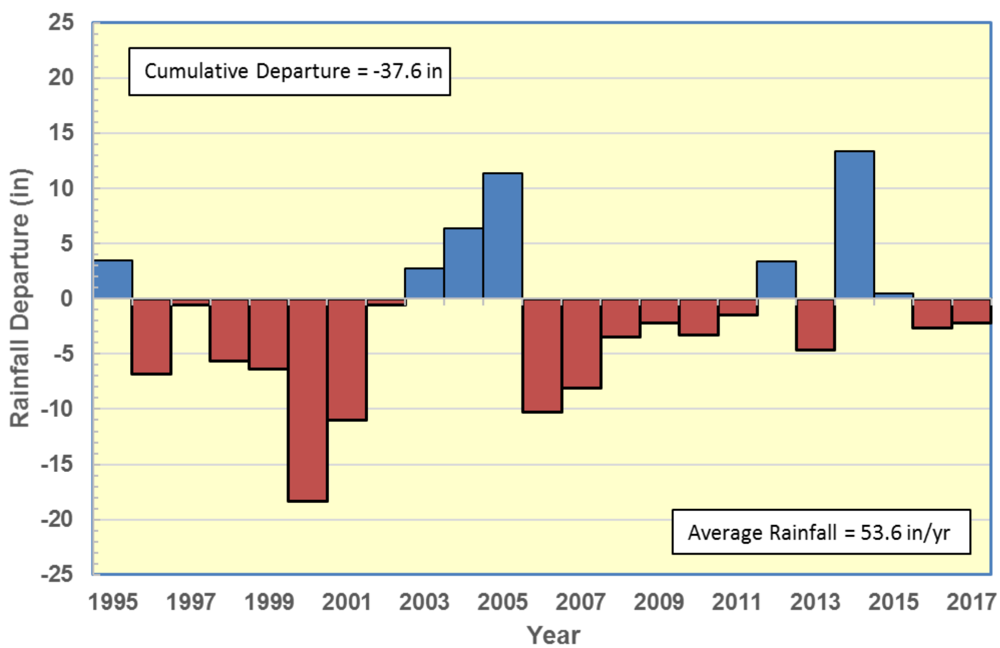


Figure 5-9. Annual departure in radar-estimated rainfall in the Homosassa springshed from 1995 through 2017.

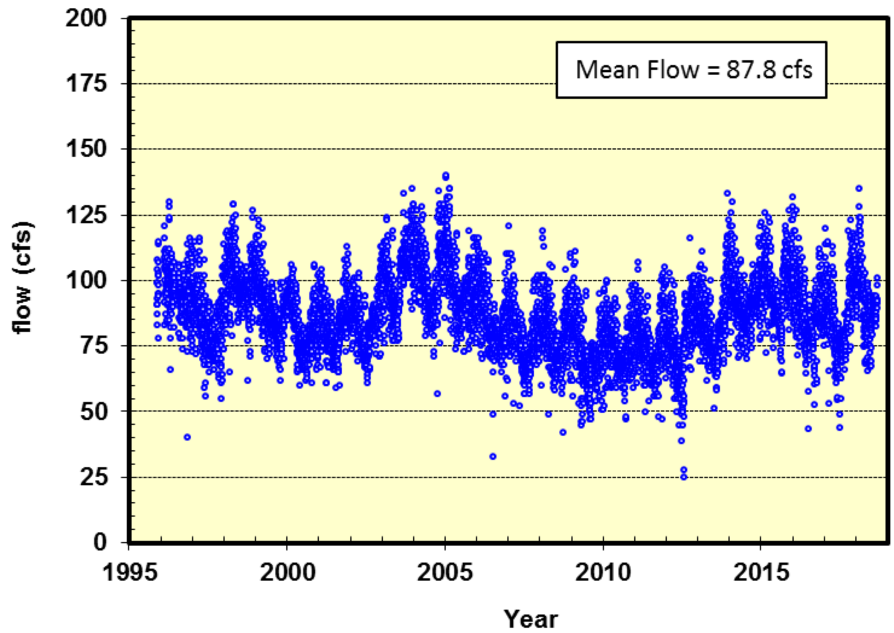


Figure 5-10. Daily flow at Homosassa No. 1 Spring from October 1995 to August 2018. Source: USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678).

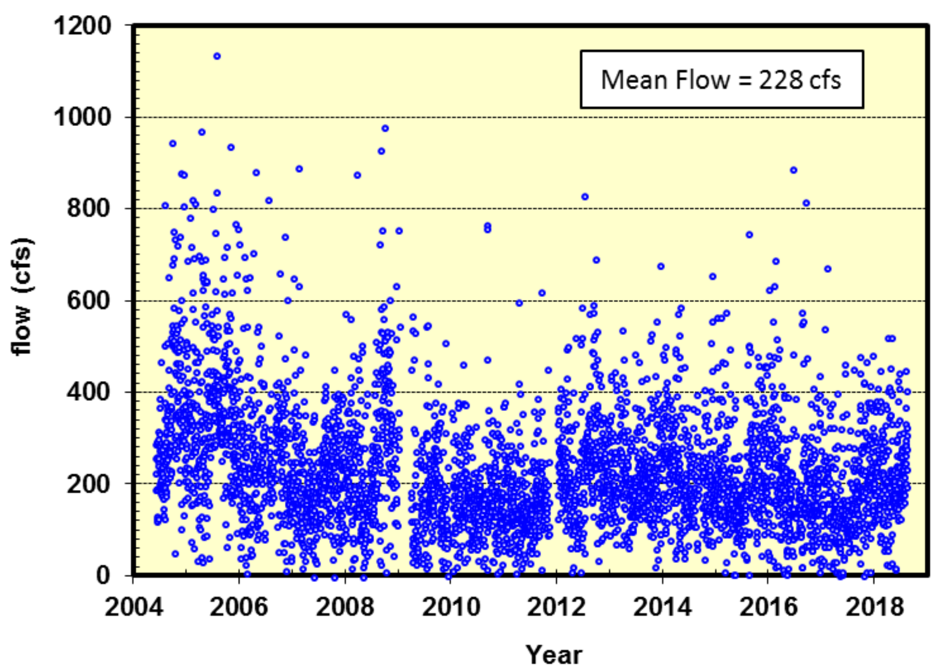


Figure 5-11. Tidally-filtered daily flow at Homosassa River from May 2004 to August 2018 (Source: USGS Homosassa River at Homosassa FL Gage No. 02310700).

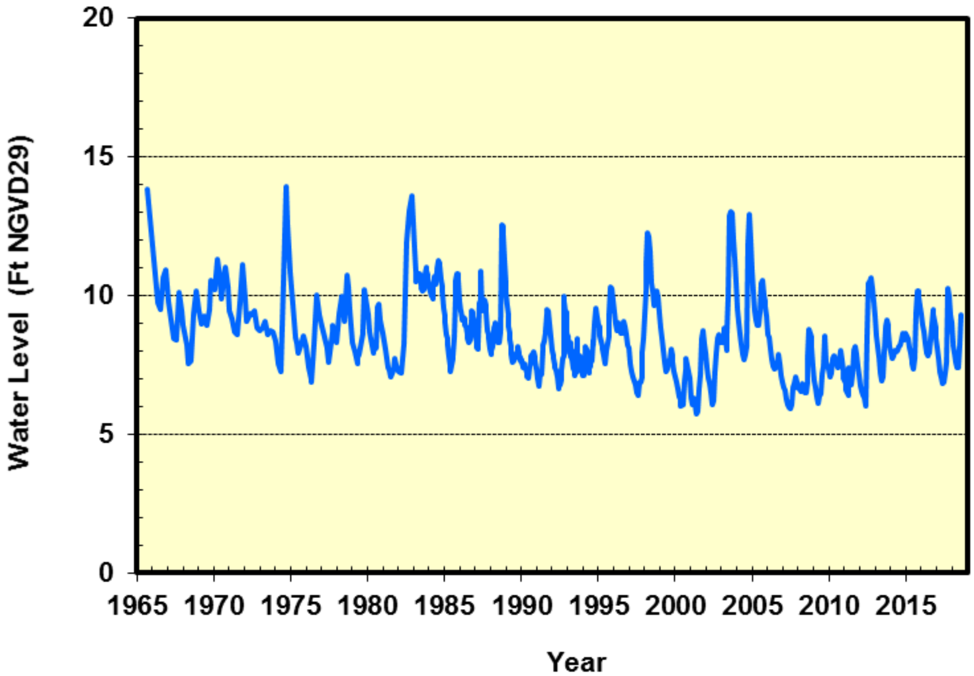


Figure 5-12. Water level history of the Lecanto 2 UFA well (September 1965 – July 2018).

Table 5-2. Linear trend and statistical significance level of Lecanto 2 UFA well water levels from 1965-2018 and 1990-2018. Statistical significance based on an alpha (p value) less than or equal to 0.05.

Period of Record	**Regression Equation**	**Slope (feet)**	**Total Water Level Change (feet)**	**Statistical Significance (p value$\leq$0.05)**
1965-2018	y = -0.0349x + 78.06	-0.0349	-1.84	<0.01
1990-2018	Y = 0.0049x – 1.79	+0.0049	+0.11	0.52

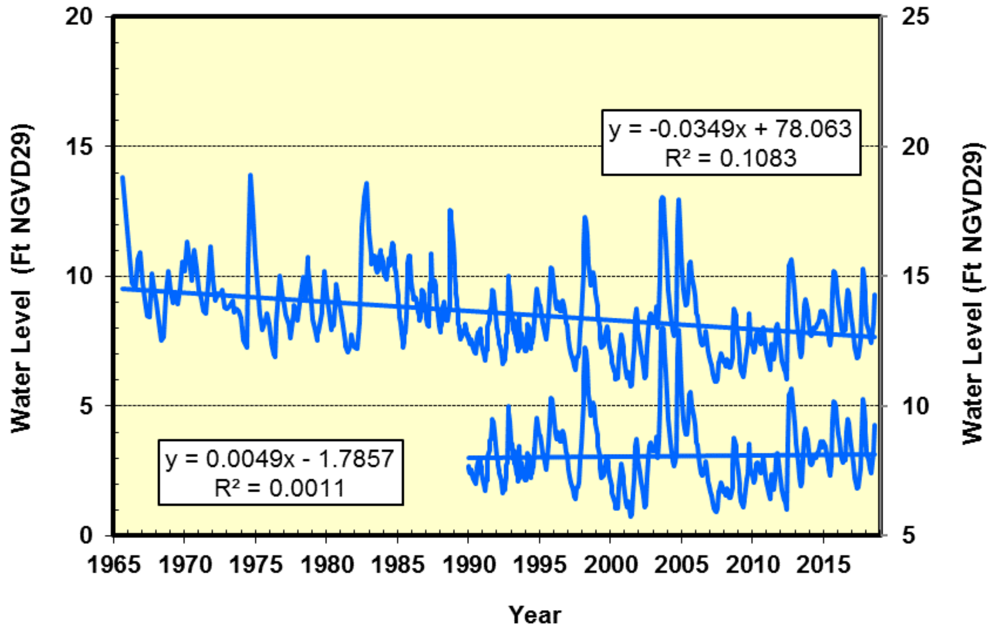


Figure 5-13. Simple linear regression of the Lecanto 2 UFA well water level trend from 1965-2018 and 1990-2018 (Note: Hydrograph from 1990-2018 assigned to secondary y-axis for viewing purposes).

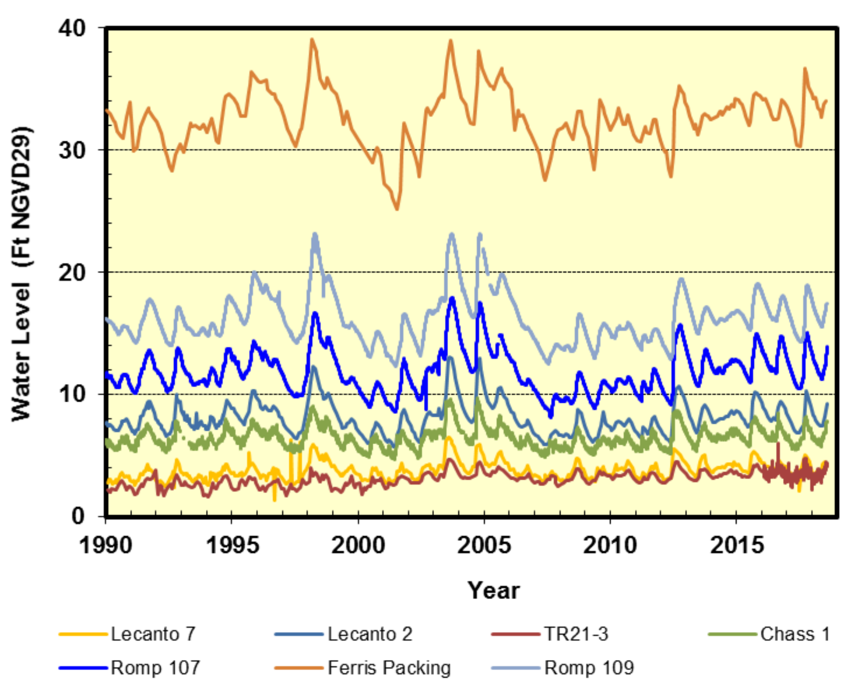


Figure 5-14. Water level history from 1990-2018 for seven UFA monitor wells within or near the Homosassa and Chassahowitzka springsheds.

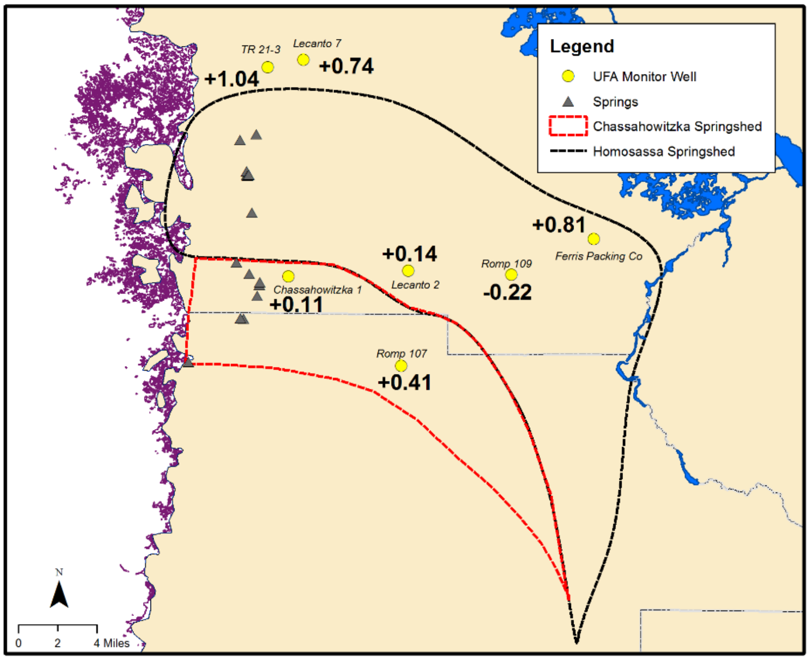


Figure 5-15. Water level change (ft) from 1990 to 2018 based on linear regressions of seven UFA monitor wells within or near the Homosassa and Chassahowitzka springsheds.

Table 5-3. Linear trend and statistical significance level of seven UFA monitor well water levels from 1990-2018 within or near the Chassahowitzka and Homosassa springsheds. *Statistical significance based on an alpha (p value) less than or equal to 0.05*

Well Name	Regression Equation	Slope (feet)	Total Water Level Change (feet)	Statistical Significance (p value<0.05)
Chassahowitzka 1	y = 0.0038x - 1.19	0.0038	0.11	< 0.01
Romp 107	y = 0.0147x - 17.57	0.0147	0.41	< 0.01
Lecanto 2	y = 0.0049x -1.79	0.0049	0.14	0.52
Ferris Packing Co.	y = 0.029x - 25.98	0.029	0.81	0.08
Romp 109	y = -0.0077x + 31.78	-0.0077	-0.22	< 0.01
TR21-3	y = 0.037x - 71.15	0.037	1.04	< 0.01
Lecanto 7	y = 0.0266x - 49.47	0.0266	0.74	< 0.01

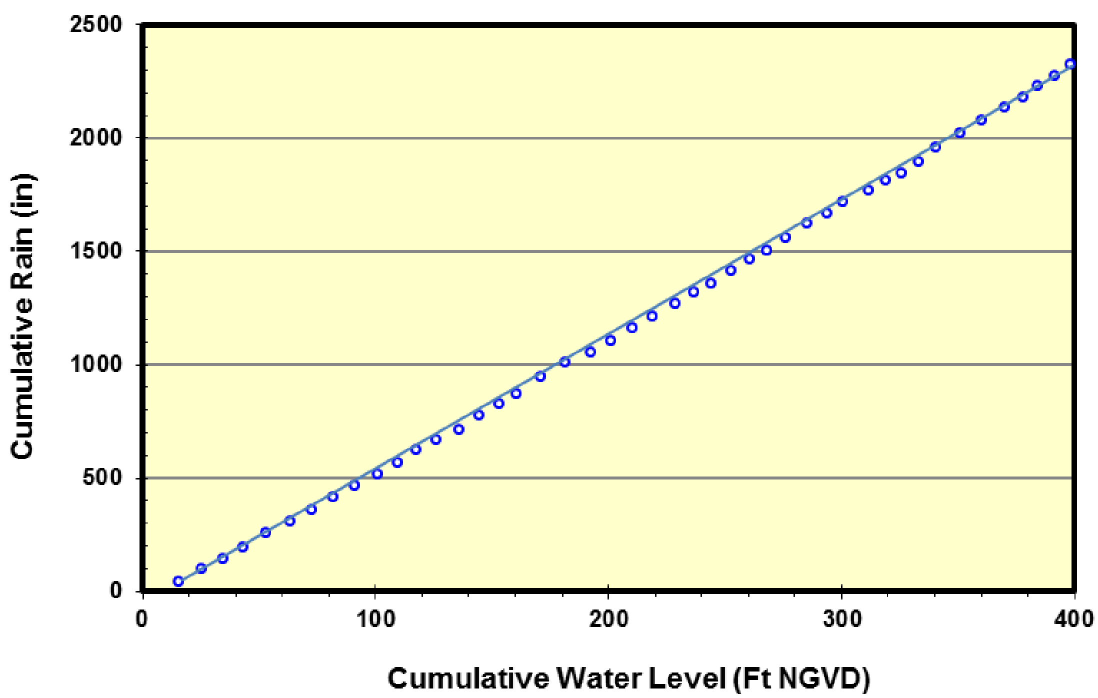
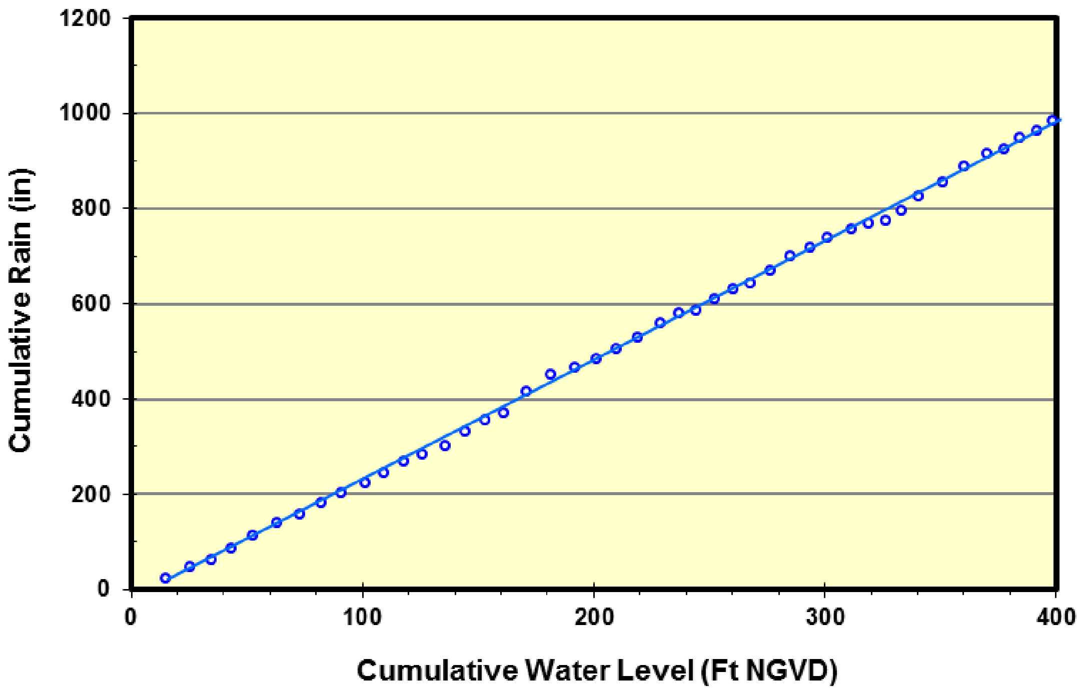


Figure 5-16. Cumulative sum of annual water levels at the Lecanto 2 well and average annual rainfall from the Brooksville, Inverness, and Ocala NWS stations from 1965-2017.



Note Trimmed 30 inches from annual rainfall each year

Figure 5-17. Cumulative sum of annual water levels at the Lecanto 2 well and average annual rainfall from the Brooksville, Inverness, and Ocala NWS stations from 1965-2017.

5.4 Impacts of Groundwater Withdrawals on the Homosassa River System

The Northern District groundwater flow model (NDM) was used to predict the impacts of groundwater withdrawals on flow of the Homosassa Spring Group. A water budget was also developed for the springshed to serve as a verification of model results.

5.4.1 Predicting Groundwater Withdrawal Impacts Using the Northern District Model

The NDM was originally developed in 2008 by Hydrogeologic, Inc. (HGL) (Hydrogeologic, 2008). Since that time, there have been several refinements to the original model, with subsequent Version 2.0 in 2010 and Version 3.0 in 2011. In 2013, Version 4.0 was completed by expanding the model grid slightly northward and east to the St. Johns River. This was done as a cooperative effort between the District, St. Johns River Water Management District (SJRWMD), Marion County, and the Withlacoochee River Regional Water Supply Authority (Hydrogeologic, 2013). The domain of the NDM includes portions of the SWFWMD, the SJRWMD, and the Suwannee River Water Management District. The flow model encompasses the entire extent of the Central West-Central Florida Groundwater Basin (CWCFGWB) and the Northern West-Central Florida Groundwater Basin (NWCFGWB) and portions of the Northern East-Central Florida Groundwater Basin. The eastern boundary of the regional groundwater flow model extends to the St. Johns River, while the western boundary of the model domain extends approximately five miles offshore in the Gulf of Mexico (Figure 5-18). Version 5.0 was completed in August 2016 (Hydrogeologic, Inc. and Dynamic Solutions, 2016). Versions 4.0 and 5.0 were peer reviewed by Dr. Mark Stewart, P.G. and Dr. Pete Anderson, P.E.in a cooperatively-funded project for SJRWMD and SWFWMD (Anderson and Stewart, 2016; Basso 2019b [Appendix 5]). Dr. Stewart indicated in his most recent peer review that the *"NDM, Version 5.0, is the best numerical groundwater flow model currently available for assessing the effects of withdrawals in the central (Florida) springs region."*

The regional model grid consists of 212 columns and 275 rows with uniform grid spacing of 2,500 feet. The active model grid covers about 8,000 square miles in North-Central Florida. Seven active layers in the model represent the primary geologic and hydrogeologic units including: 1) Surficial Sand, 2) ICU, 3) Suwannee Limestone, 4) Ocala Limestone, 5) Upper Avon Park Formation, 6) MCU I and MCU II, and 7) Lower Avon Park Formation or Oldsmar Formation. The UFA is composed mainly of Suwannee Limestone (where it exists), Ocala Limestone, and Upper Avon Park Formation. The LFA is composed of the permeable parts of both the Lower Avon Park and the Oldsmar Formations. Because of the permeability contrast between the units, each unit is simulated as a discrete layer rather than using a single layer to represent a thick sequence of permeable formations within the UFA. This model is unique for West-Central Florida in that it is the first regional flow model that represents the groundwater system as fully three-dimensional. Prior modeling efforts, notably Ryder (1982, 1985), Sepulveda (2002), Knowles et al. (2002), and Motz and Dogan (2004), represented the groundwater system as quasi-three dimensional.

A tremendous amount of hydrologic and geologic data was utilized to construct and calibrate the NDM. The District utilized hydraulic and geologic information from more than 50 Regional Observation and Monitoring-Well Program (ROMP) sites in the SWFWMD model area. At nearly every site, coring of the earth materials occurred from land surface to more than 1,000 feet below land surface. Aquifer permeability was tested via slug tests and packer tests at specified intervals within each aquifer. Monitor wells were installed in each aquifer to measure water levels through time. The District installs continuous recorders or manually measures these monitor well water levels every month. This data is stored within the District's WMIS; some of the wells have a water-level history of 30 to 50 years. Aquifer performance tests were conducted at some of the sites to measure water level response in the UFA from temporarily pumping it at high rates. All this information assists District scientist's in understanding how the aquifer system responds to groundwater withdrawn and helps us build better models that represent the real world.

The NDM Version 5.0 was calibrated to steady-state 1995 calendar year conditions and transient conditions from 1996 through 2006 using monthly stress periods. The model was also verified for 2010 steady-state conditions. The calibration process simply involves modifying aquifer parameters within a reasonable range in the model to best match measured aquifer water levels at wells and springflows recorded by the USGS. This process accounts for some of the uncertainty in aquifer parameters between data points.

If a model can closely replicate aquifer water levels and flow through time, then it is deemed well-calibrated. This in turn provides confidence that it is an effective tool to make predictions. In 2010, water levels from over 384 observation wells in the Upper Floridan aquifer were compared with simulated water levels at each well location within the model domain (Figure 5-19).

The groundwater flow and solute transport modeling computer code MODHMS was used for the groundwater flow modeling (Hydrogeologic 2011). MODHMS is an enhanced version of the USGS modular, three-dimensional groundwater flow code (McDonald and Harbaugh 1988). This code was selected because of its powerful ability to simulate variably saturated conditions in Layer 1 coupled with its ability to model saltwater intrusion as a solute transport model in the northern region of the District.

The aquifer system is more complex in a karst-dominated system. While the location and geometry of most buried karst is unknown, there are model codes available that explicitly simulate karst conduits and aquifer matrix in a separate manner rather than integrating both within a model grid cell under a standard porous media approach. Based on a comparison of the application of the MODFLOW Conduit Flow Package and a standard MODFLOW application at Wakulla Springs by Kuniansky (2016), however, the standard MODFLOW porous medium approach was found to be an acceptable and reliable prediction tool for aquifer heads and flows in a karst geologic setting. As such, the NDM5 model as developed is useful in evaluating regional changes in stress to the system for annual, monthly, or seasonal average conditions.

In NDM Version 5.0, mean water level error (simulated minus observed) in the UFA for 1995 and the 1996-2006 average transient period was +0.17 feet and +0.41 feet, respectively (Hydrogeologic, Inc. and Dynamic Solutions, 2016). The mean absolute error varied from 3.77 to 3.61 feet for both periods, respectively, based on 137 wells in 1995 and 157 wells from 1996-2006. These statistics were for wells within the 4,600-square mile NWCFGWB. The mean error for Homosassa No. 1 Spring flows (simulated minus observed) for 1995 was minus one percent and for the 1996-2006 period was zero percent. Mean error during the 2010 verification period was minus one percent.

To determine potential impacts to Homosassa Spring group flow, 2010, 2015, and projected 2040 groundwater withdrawals with and without conservation/reuse were simulated in the NDM under long term transient conditions (five years) and compared to pre-pumping conditions (zero withdrawals) by running the model one year under transient conditions. Groundwater withdrawals include both water use permitted and domestic self-supply withdrawals. The UFA heads and springflows generated at the end of each period were subtracted from UFA heads and springflows at the end of the pre-pumping simulation to determine aquifer water level drawdown and flow changes. The model predicts UFA drawdown of approximately 0.1 feet from pre-pumping to 2015 conditions at Homosassa No. 1 spring. The predicted reduction in Homosassa Spring group flow from pumping in each period is shown in Table 5-4. Simulated springs for the Homosassa spring group in the NDM5 include Halls River Head, Halls River No. 1, Belcher, Abdoney, McClain, Trotter, Homosassa No. 1, Pumphouse, Hidden River Head, and the SE Folk Homosassa springs. Predicted flow changes range from 1.9 percent due to 2015 pumping to 2.5 percent due to projected 2040 withdrawals without conservation and reuse. Predicted flow impacts are reduced to 2.1 percent in 2040 with planned conservation and reuse projects.

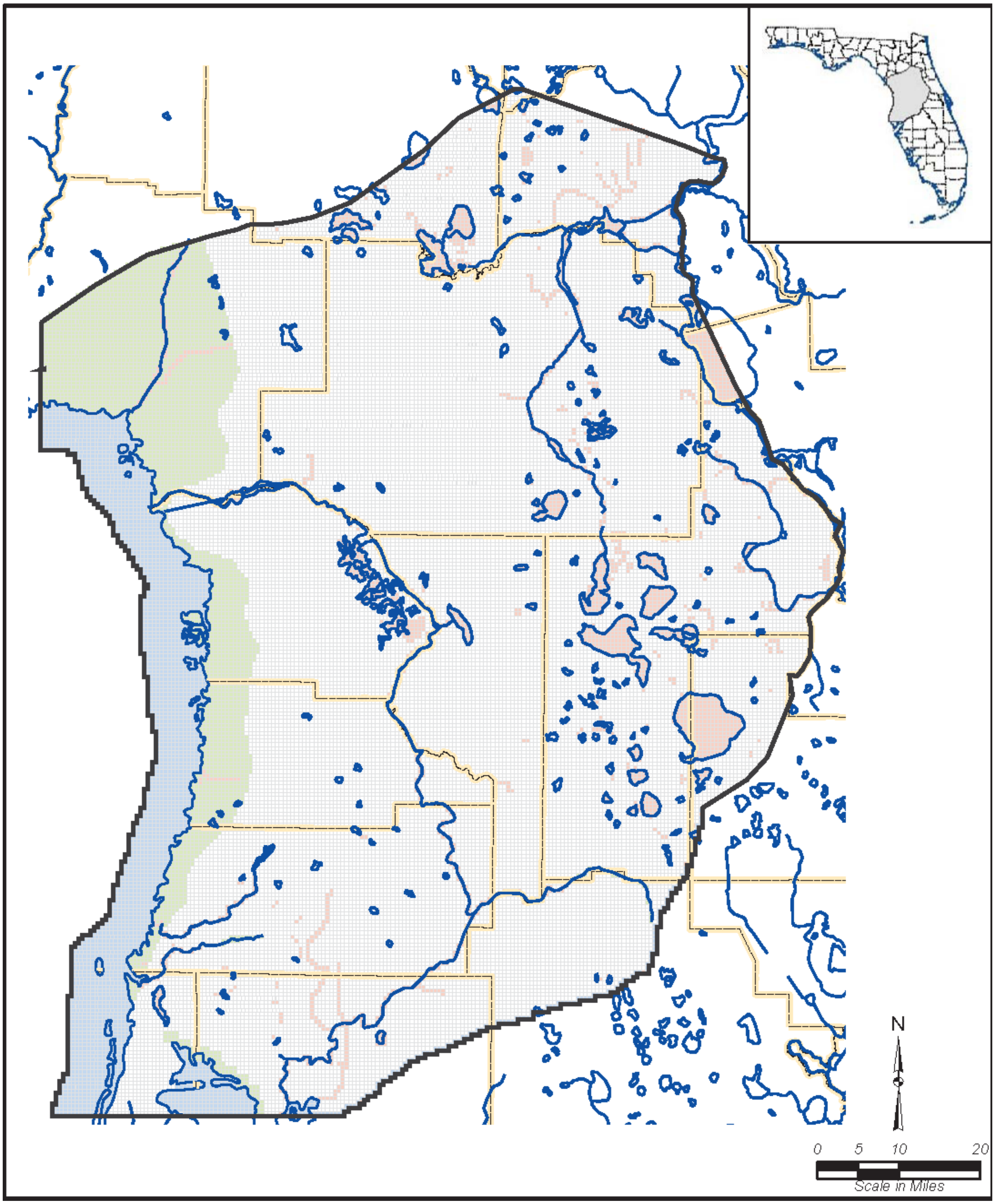


Figure 5-18. Northern District groundwater flow model, Version 5.0, model grid.

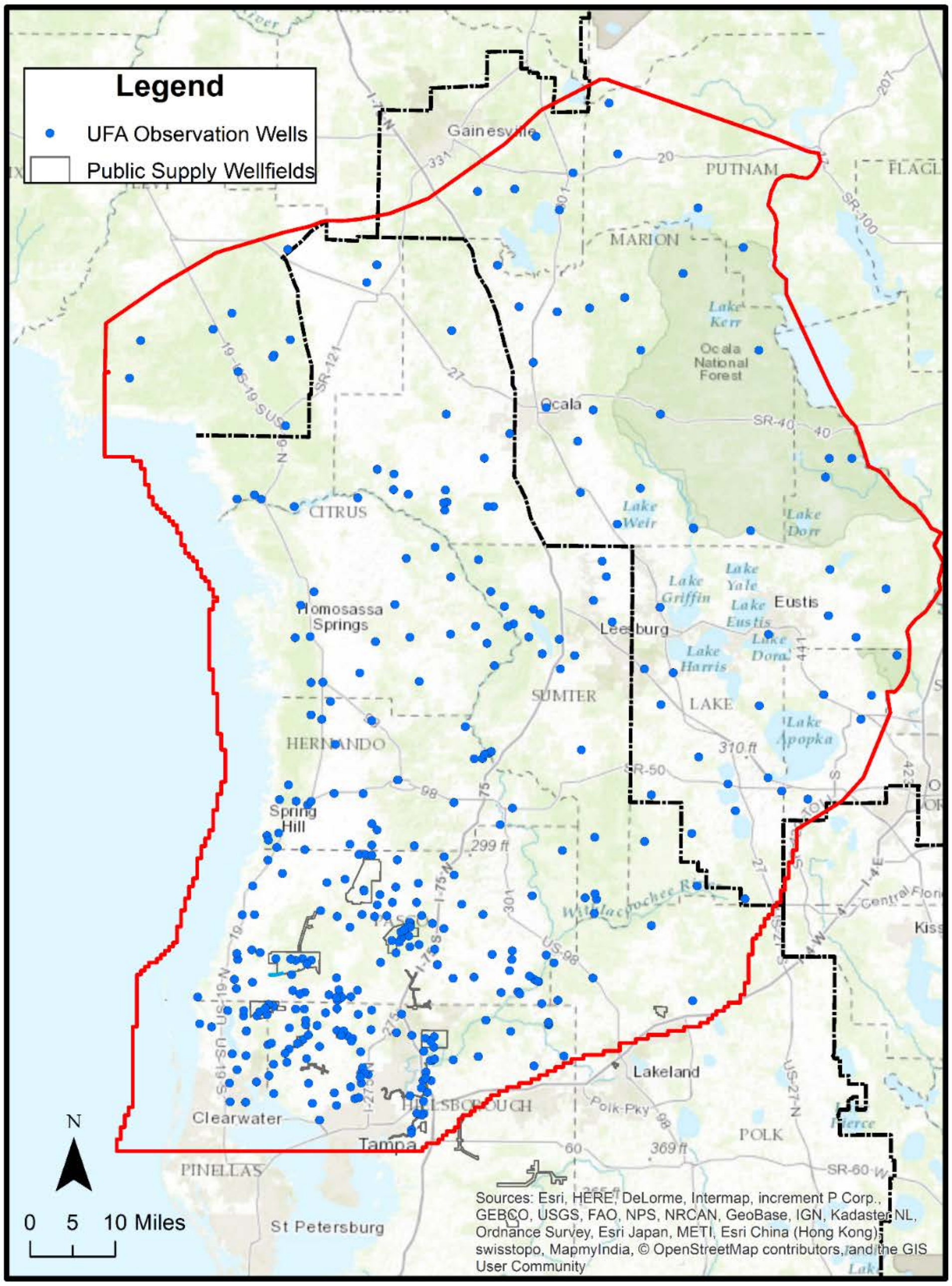


Figure 5-19. Location of Upper Floridan aquifer target wells used in the Northern District groundwater flow model for 2010.

Table 5-4. Predicted flow changes for Homosassa Spring Group from the Northern District groundwater model, Version 5.0, due to groundwater withdrawals in 2010, 2015, and 2035.

Year	Model-wide Groundwater Withdrawals (mgd)	Non-pumping springflow (cfs)	Pumping Springflow (cfs)	Difference (cfs)	Difference (percent)
2010	479.1	261.91	257.09	4.82	-1.8
2015	446.4	261.91	257.05	4.86	-1.9
2040	596.2	261.91	255.45	6.46	-2.5
2040 with Conservation & Reuse	540.8	261.91	256.29	5.62	-2.1

5.4.2 Water Budget and Groundwater Withdrawals in the Vicinity of Homosassa Springs

A water budget for the Homosassa springshed (261 sq. miles) was developed using the period of record mean annual discharge from the springs based on no change in storage. Long-term average flow for the Homosassa Spring group is estimated at 166.1 mgd (257 cfs) based on simulated flow rates within the NDM 5 model for 2015. Groundwater withdrawals in 2015 (from metered and estimated water use) were 8.1 mgd (12.5 cfs). Estimated water use includes domestic self-supply.

A water budget analysis uses mass balance to estimate the impacts of withdrawals on springflow. For example, imagine a tiny hypothetical springshed that discharges 10 gallons per year from its only spring. If 1 gallon is withdrawn from its springshed, we might expect for springflow to be reduced by that same 1 gallon, so impacts would be 1/10 = 10% in this hypothetical scenario. However, some proportion, for example 50%, of every gallon withdrawn will be returned to the springshed as non-consumptive use. Therefore, in this hypothetical example, the 1 gallon withdrawn would result in a 0.5 gallon reduction in springflow, equating to a (0.5/10 = 0.05) 5% impact. Additional factors make this an overestimate of impacts because 1 gallon of consumptively withdrawn water will result in less than 1 gallon of reduction to springflow since water can be derived from other sources besides springflow. The actual numbers for this Homosassa springshed budget analysis are detailed below.

The 2015 estimate of withdrawals for the springshed were 8.1 mgd, which amounts to 4.9 percent of the 166.1 mgd average flow for the spring group in 2015 (8.1/166.1 = 0.049). The USGS, however, estimates that on average only 45% of water withdrawn is consumptively-used (Marella 2008). This means that for every 100 gallons withdrawn, 55 gallons make their way back into the groundwater system in the springshed. Applying this factor to the total groundwater withdrawn in the springshed, and conservatively assuming every gallon of consumptively-used water results in a gallon decline in springflow, this would equate to a flow decline of 2.2 percent due to withdrawals in the springshed (8.1 mgd * 0.45 = 3.6 mgd; 3.6 mgd/166.1 mgd = 2.2%). This is a conservatively high assumption because groundwater withdrawal impacts are offset by changes in storage (water level decline); induced leakage from the surficial aquifer, lakes and wetlands; reductions in evapotranspiration (ET), runoff, and lateral groundwater outflow to the coast; and reductions in groundwater seepage to lakes and rivers. Therefore 100% of consumptively-used water cannot all be subtracted from springflow. For example, just a little more than a two percent reduction in 32 in/yr of evapotranspiration (398 mgd), would account for all groundwater withdrawn in the springshed (398 mgd * 0.0204 = 8.1 mgd).

The state-wide average consumptive use percentage of 45% from the USGS was checked against estimates for the 4,600 square mile groundwater basin (NWCFGWB) which includes the Homosassa springshed. In 2013, the total groundwater withdrawn in the basin was estimated at 163 mgd (0.75 inches), while the total estimate of return water from septic tanks, reclaimed water facilities, and irrigation was 94 mgd (0.43 inches). This yielded a consumptive use ratio of 42 percent (163 – 94 = 69; 69/163 = 0.42). Thus, the 45% consumptive use ratio from the USGS is slightly more conservative than the estimate for the larger groundwater basin because it assumes less water is returned to the springshed following withdrawals.

The District maintains a metered and estimated water use database from 1992 through 2016. Maps of the spatial distribution of groundwater withdrawals within the springshed each year from 1992 through 2016 are contained in Basso (2019b [Appendix 5]). Water use permitted groundwater withdrawals in the Homosassa Springshed for 2015 are shown in Figure 5-20. Domestic self-supply well withdrawals within the springshed are depicted in Figure 5-21. Individual, permitted groundwater withdrawals typically show withdrawal rates less than 0.5 mgd, and are scattered throughout the springshed. Some larger withdrawals are located directly to the east of Homosassa spring group and east of the City of Brooksville. Domestic self-supply well withdrawals are estimated per square mile within the springshed. Groundwater withdrawals have declined since reaching their peak of 10 mgd in 2006 and since 2010 the trend in springshed groundwater use has essentially remained flat (Figure 5-22). In 2015, water use permitted groundwater withdrawals based on estimated and metered use were 6.6 mgd with another 1.5 mgd estimated for domestic self-supply.

The trend in springshed groundwater use is similar to the overall trend within the SWFWMD Northern Planning region which includes all or parts of Citrus, Hernando, Lake, Levy, Marion, and Sumter Counties. Groundwater use in the planning region in 2015 was 114.2 mgd, down from its peak in 2006 of 161.4 mgd (Figure 5-23). Groundwater withdrawn in the District's six northern counties represented only 15 percent of 785 mgd of groundwater withdrawn in the SWFWMD in 2015.

In the 4,600 square-mile NWCFGWB, which includes the District's northern six counties plus portions of Marion and Lake Counties within the SJRWMD, groundwater withdrawals in 2015 (0.83 in) made up just six percent of annual recharge (14.2 in) based on average rainfall conditions. Consumptively-used withdrawals were a little less than three percent of average recharge in the groundwater basin.

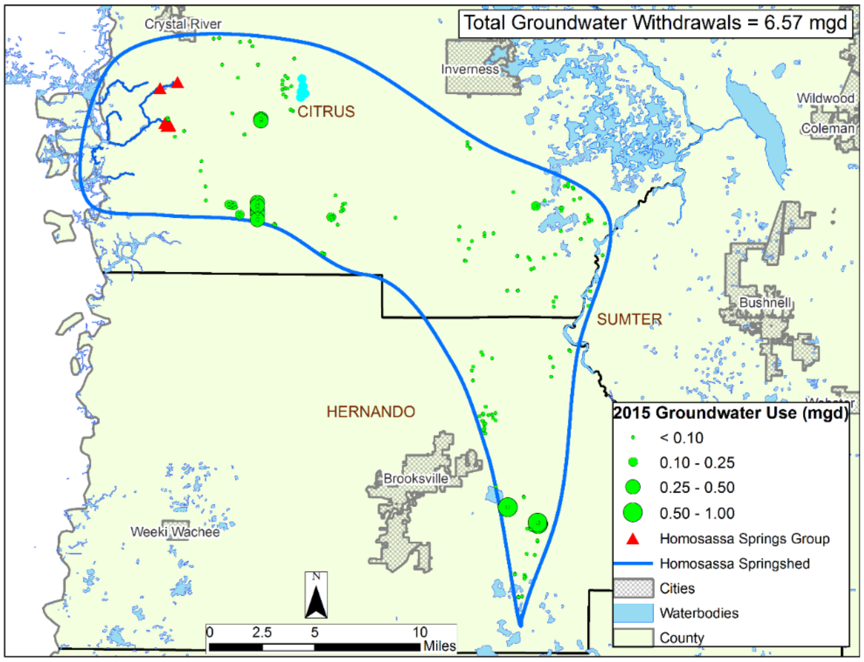


Figure 5-20. Water use permitted groundwater use in the Homosassa springshed in 2015.

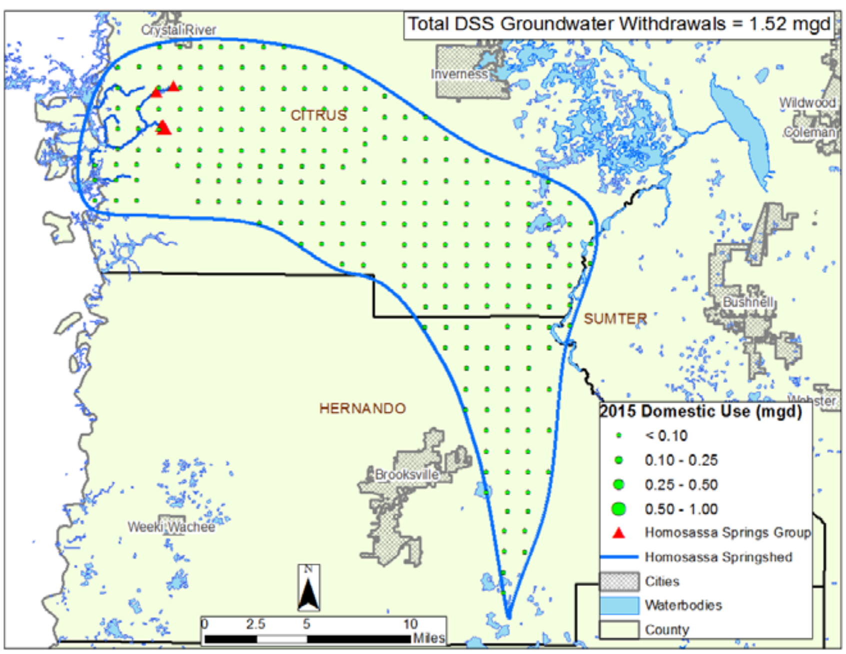


Figure 5-21. Estimated Domestic self-supply groundwater use in the Homosassa springshed in 2015.

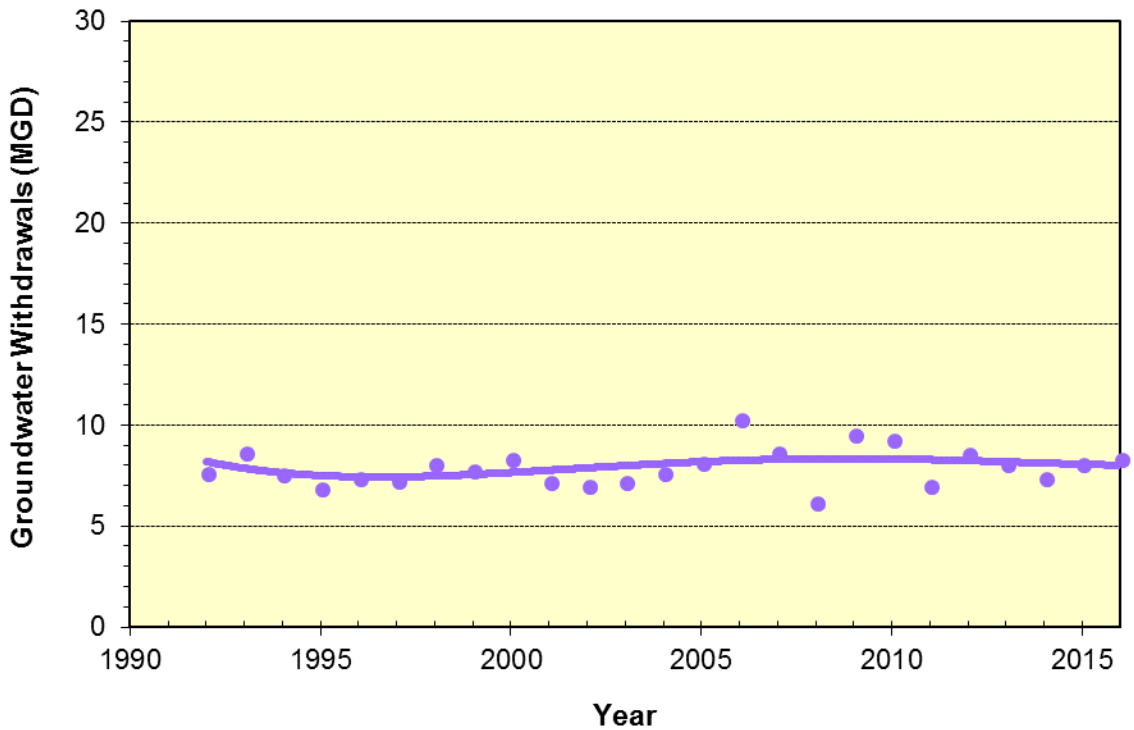


Figure 5-22. Estimated and metered groundwater use history within the Homosassa springshed from 1992 through 2016, includes estimates for domestic-self supply (Solid line is a 4th order polynomial fit to annual data).

5.4.3 Permitted Groundwater Withdrawals in the Northern Planning Area

In addition to estimated and metered water use, the magnitude of permitted groundwater and the number of permits existing per year were examined in the Northern Planning area of the District to note any trends. This area includes all or portions of six counties: Citrus, Hernando, Lake, Levy, Marion and Sumter.

The total permitted groundwater use in 2017 was 190.6 mgd for the District's six northern counties. This has declined slightly since reaching its peak of 199.9 mgd in 2008 (Figure 5-24). In Citrus and Hernando Counties, permitted groundwater use has declined from 99.3 mgd in 2008 to 78.3 mgd in 2017. The number of permits in the northern six counties has also dropped from 714 in 2011 to 676 in 2017 (Table 5-5).

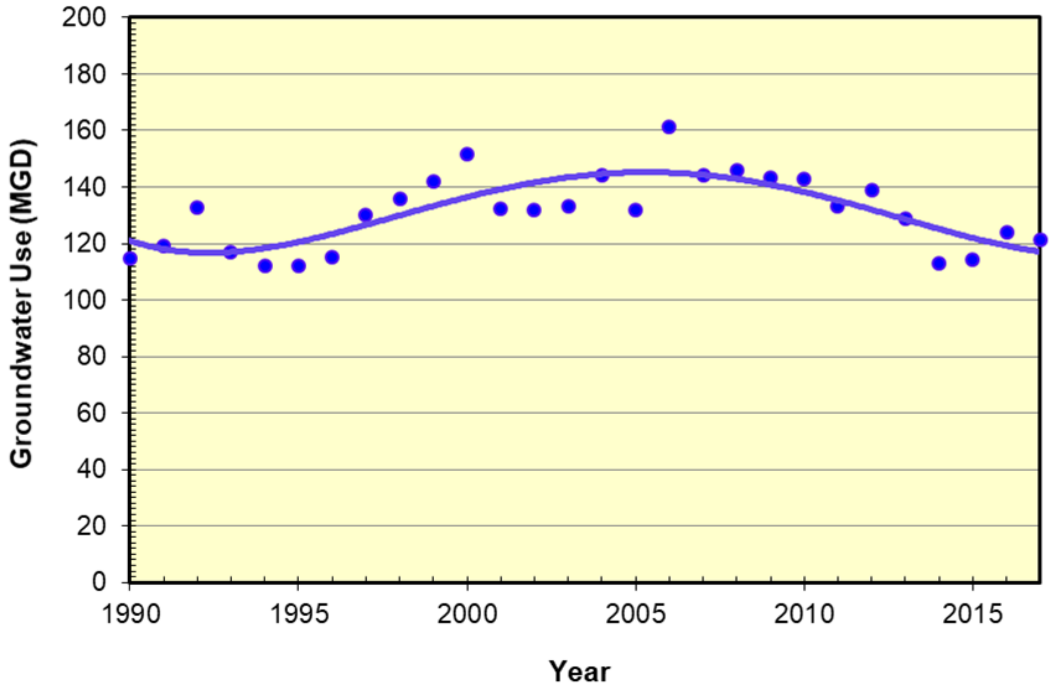


Figure 5-23. Estimated and metered groundwater withdrawal history within all or the portion of six counties within the District's Northern Planning Region, including: Citrus, Hernando, Lake, Levy, Marion, and Sumter counties; from 1992 through 2017, includes estimates for domestic-self supply (Solid line is a 4th-order polynomial fit to the annual data).

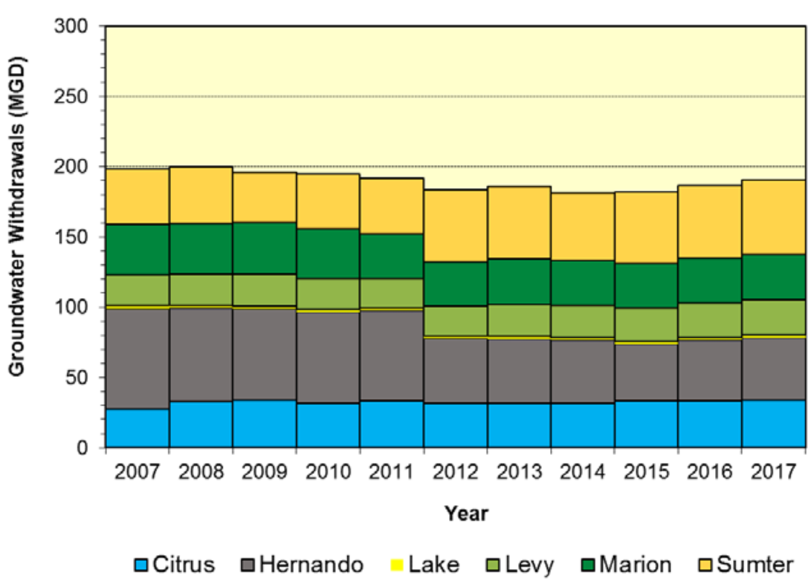


Figure 5-24. Permitted groundwater quantity in District portion of the six counties of the District's Northern Planning Region (2007-2017).

Table 5-5. Number of Water Use Permits existing in each of the six counties in the District's Northern Planning Region (2011-2017).

Year	Citrus	Hernando	Lake*	Levy*	Marion*	Sumter	Total
2011	121	135	20	96	146	196	714
2012	121	135	19	92	140	197	704
2013	121	136	19	92	140	192	700
2014	118	136	19	90	140	190	693
2015	122	124	16	92	135	189	678
2016	121	129	17	90	132	187	676
2017	121	127	17	93	131	187	676

*SWFWMD portion only

CHAPTER 6 - MODEL RESULTS

6.1 Groundwater modeling

Northern District Model version 5 (NDM5) simulations indicate current (2015) withdrawals have reduced unimpacted flows in the Homosassa River System by 1.9% (See Chapter 5).

6.2 Habitat Impacts

How much have groundwater withdrawals affected habitats in the system? How much might further incremental reductions in flow affect habitats? These questions are quantitative, in the sense that we want to identify numeric estimates of habitat loss corresponding to numeric reductions in flow. We addressed these questions using the LAMFE hydrodynamic model to predict quantitative changes to salinity and temperature-based habitats in response to incremental reductions in flow.

6.3 LAMFE Modeling

The LAMFE model (Chen 2011) was used to predict salinity and temperature throughout the Homosassa River System (Figure 6-1) (Chen 2019a [Appendix 6]). During the calibration process for this hydrodynamic model, model parameters were tuned to achieve the best fit between model results and measured data (Table 6-1). Once the model was calibrated, model predictions of water levels, salinities, and temperatures were compared against measured data during for a 15-month (2016-06-01 to 2017-08-31) verification period without further tuning parameters. Verification results indicated the model was able to predict measured values during this verification period with statistics shown in Table 6-3. These results support our use of model output for development and use of criteria supporting reevaluation of minimum flows for the Homosassa River System.

Flow inputs to the system included reported flows at the USGS Homosassa Springs at Homosassa Springs, FL gage (No. 02310678), SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688), Halls River at Homosassa Springs, FL (No. 02310689), and Hidden River near Homosassa, FL gage (No. 02310675) gages, and flow estimates based on these reported flows. Flows from Homosassa Springs at Homosassa Springs, FL gage (No. 02310678), SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688), Halls River at Homosassa Springs, FL gage (No. 02310689) were added at the most upstream cross sections corresponding to actual locations of springs. Flows at Otter Creek were added along main stem of Homosassa River at site of confluence with Otter Creek. Otter Creek flows were estimated as equal to flows in Hidden River, due to hydrological connection between these waterways (Karst Underwater Research, Inc. 2011). The first date for reported discharge at the Halls River gage (02310689) is 2012-03-10. For dates prior to then, discharges were estimated for the gage site from regression with flows at the SE Fork Homosassa Spring at Homosassa Springs, FL gage (No. 02310688).

Boundary conditions at the river mouth were based on measured data at the USGS Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712). Gaps in boundary condition data existed at this gage from 2009-10-06 to 2014-10-31 for water elevation and temperature and from 2009-01-06 to 2014-11-04 for salinity. These gaps were filled through regression with data from the Chassahowitzka R at Mouth nr Chassahowitzka, FL gage (No. 02310674). Additional boundary condition data at Mason Creek and the Salt River came from specific conductance, temperature and water depth measurements made from March through August 2017, because there are no long-term gaging stations at these boundaries. Regression equations were developed to estimate boundary conditions at Mason Creek and Salt River from data reported at the Homosassa River at Shell Island near Homosassa, FL gage (No. 02310712). Meteorological data were from the Lecanto High UF/IFAS FAWN station for the period from 2013-07-02 to 2018-03-12. Earlier meteorological data from the Inglis Dam station (WMIS ID No. 22960).

Scenario runs (simulations) were conducted from 2007-10-09 to 2018-03-12 (10 y, 5 mo.). Model scenarios included unimpacted flows (that is, flows that would have existed in the absence of withdrawal impacts), existing flows, and reductions from unimpacted flows (Table 6-2). Changes to boundary conditions due to modeled flow reductions were accounted for.

Salinity-based habitats were considered three ways: as total volume of water, as bottom area, and as shoreline length. All were estimated as the total habitat associated with various salinity ranges. Salinity ranges assessed included those less than or equal to 1, 2, 3, 5, 10, 15, and 20 psu. For each flow reduction scenario, the quantity of each salinity-based habitat was compared with the corresponding habitat available under the unimpacted flow scenario. Linear interpolation was used to find the exact flow reduction corresponding to a 15% decrease in habitat when flow reduction scenarios bracketed this value. For example, a 10% flow reduction may have reduced the volume of habitat associated with a specific salinity range by 14%, while a 12.5% flow reduction may have reduced the shoreline habitat by 16%. Linear interpolation of these specific results would yield an 11% flow reduction (rounded to the nearest whole-percentage change) that would be associated with a 15% change in habitat.

Results of the salinity-based habitat simulations indicated that the most sensitive modeled response to flow reduction was associated with changes in the volume of water and bottom area less than 2 psu (Table 6-4). A flow reduction of 11% was associated with a 15% decrease in these two habitats.

Temperature-based habitats were considered specifically to avoid stress in Florida Manatee (*Trichechus manatus latirostris*) and Common Snook (*Centropomus undecimalis*). Stressful conditions for Common Snook occur when temperatures drop below 15° C for 24 hours or more. Stressful conditions for manatees occur if they are exposed to water less than 20° C for 72 hours (Chronic stress) or 15° C for 4 hours (Acute stress). The most stressful times for manatees were found by identifying the coldest average 72-hour and 4-hour time periods in the simulation. During these most stressful periods, flow reduction scenarios were compared with the unimpacted scenario. Temperature-based habitat was considered in terms of volume of water and total area of habitat. Waters less than 3.8 feet deep were excluded from habitat assessment for manatee based on typical animal size.

Results of the temperature-based habitat simulations for the Common Snook showed that a 15% reduction in area of suitable habitat (> 15° C) during the coldest 24 hours occurred when unimpacted flows were reduced by 5% (Table 6-5). This most sensitive response in Common Snook habitat occurred on December 14, 2010 (Figure 6-2).

Results of the temperature-based habitat analyses for the Florida Manatee showed that a 15% reduction in area of suitable habitat (> 15°C) during the coldest 4 hours occurred when unimpacted flows were reduced by 6% (Table 6-5). A fifteen percent reduction in manatee habitat is considered "presumptive" in this and previous minimum flows evaluations for the Chassahowitzka River, Homosassa River, Weeki Wachee River, and Crystal River / Kings Bay. It is possible for available warm water habitat to exceed the quantity of useable habitat based on the number of manatees expected to visit the site. For the Homosassa River System, a maximum of 281 manatees has been observed at one time. The overall habitat available when acute habitat is most sensitive to reductions in flow is 2,067,403 square feet (192,068 square meters). As noted in Chapter 4, each manatee requires 28.5 square feet. Thus, when flows are reduced by 6%, and habitat is reduced by 15% there is still room for 72,540 manatees. Therefore, the presumptive 15% reduction in habitat will not constitute a significant harm to the manatee population.

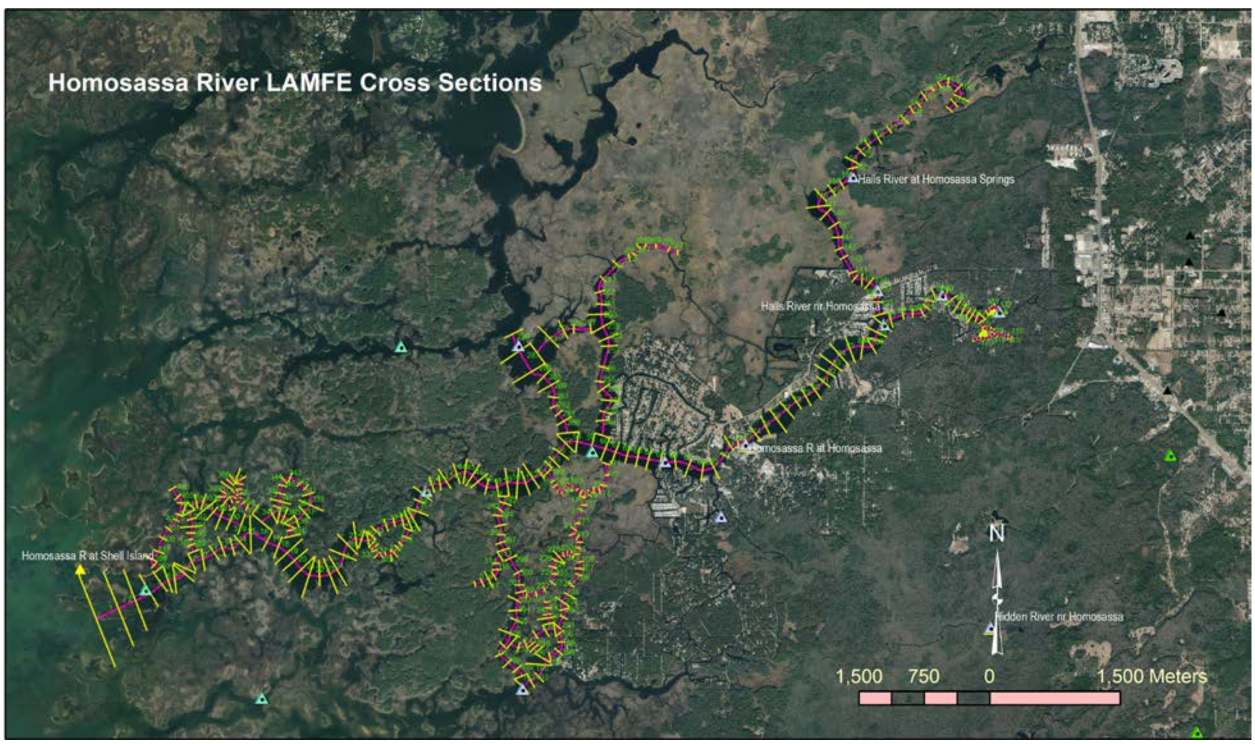


Figure 6-1. Homosassa River System hydrodynamic (LAMFE) model cross sections discretize 406 grids along the main stem of the river and 21 branches or tributaries. The horizontal spacing of the grids varies between 29 m to 277 m. The water body was discretized with 15 layers between -6.56 m, NAVD88 to 3.0 m, NAVD88, with the layer thickness varying from 0.3 m to 1.76 m.

Table 6-1. Hydrodynamic (LAMFE) model calibration, verification, and simulation periods.

Calibration	Verification	Simulation
11/4/2014 to 5/31/2016	6/1/2016 to 8/31/2017	10/9/2007 to 3/12/2018

Table 6-2. Hydrodynamic (LAMFE) model run scenarios for the Homosassa River System. Unimpacted flows calculated using withdrawal impact of 1.85% from NDM5.

Flow scenarios
Unimpacted (Existing x 1.01885)
Existing (impacted)
Unimpacted minus 2.5%
Unimpacted minus 5%
Unimpacted minus 7.5%
Unimpacted minus 10%
Unimpacted minus 12.5%
Unimpacted minus 15%
Unimpacted minus 17.5%
Unimpacted minus 20%
Unimpacted minus 22.5%
Unimpacted minus 25%
Unimpacted minus 27.5%
Unimpacted minus 30%

Table 6-3. Skill assessment metrics for the hydrodynamic model (LAMFE), based on USGS station (gage) data collected in the Homosassa River.

Parameter	USGS Station	Mean Error	Mean Absolute Error	R^2	Skill
Water Level (cm)	SE Fork Homosassa River	-1.750	5.402	0.863	0.960
	Homosassa Springs @ Homosassa Springs	-1.274	5.294	0.861	0.960
	Halls River near Homosassa	-0.763	4.957	0.879	0.966
	Halls River @ Homosassa Springs	-0.142	6.081	0.842	0.955
	Homosassa River @ Homosassa	0.648	5.643	0.849	0.959
	Average	-0.656	5.475	0.859	0.960
Salinity (psu)	SE Fork Homosassa River	0.138	0.237	0.593	0.863
	Homosassa Springs @ Homo Springs	-0.004	0.038	0.920	0.979
	Halls River near Homosassa	0.209	0.589	0.542	0.850
	Halls River @ Homosassa Springs	0.024	0.274	0.703	0.914
	Homosassa River @ Homosassa (top)	-0.160	0.730	0.737	0.918
	Homosassa River @ Homosassa (bottom)	-0.187	0.874	0.743	0.922
	Average	0.003	0.457	0.706	0.908
Temperature (°C)	SE Fork Homosassa River	0.188	0.282	0.883	0.955
	Homosassa Springs @ Homosassa Springs	0.113	0.122	0.436	0.665
	Halls River near Homosassa	0.335	0.930	0.913	0.972
	Halls River @ Homosassa Springs	-0.693	1.224	0.948	0.961
	Homosassa River @ Homosassa (top)	-0.460	0.733	0.962	0.986
	Homo River @ Homosassa (bottom)	-0.415	0.688	0.967	0.989
	Average	-0.155	0.663	0.852	0.921

Table 6-4. Salinity-based habitat impacts. Flow reductions (as percent reduction from unimpacted scenario) corresponding to a 15% decrease in available habitat are listed for 7 salinity zones. An 11% decrease in flow from the unimpacted flow corresponds to a 15% decrease in the volume and bottom area of habitat exposed to average salinities less than or equal to 2 psu.

Salinity-Based Habitat	Salinity (≤ psu)						
	1	2	3	5	10	15	20
Volume	>30%	11%	13%	15%	>30%	>30%	>30%
Bottom Area	>30%	11%	13%	15%	>30%	>30%	>30%
Shoreline Length (Altered)	>30%	19%	20%	27%	>30%	>30%	>30%
Shoreline Length (Natural and Vegetated)	>30%	14%	12%	12%	>30%	>30%	>30%

Table 6-5. Temperature-based habitat impacts. Flow reductions (as percent reduction from unimpacted scenario) corresponding to 15% decrease in available habitat are listed for chronic and acute Florida manatee thermal habitat and Common Snook thermal habitat. A 5% decrease in flow from the unimpacted flow corresponds to a 15% decrease in the area of Common Snook habitat with temperatures greater than 15°C during the most sensitive 24-hour period.

Temperature-Based Habitat	Florida Manatee Temperature Stress and Habitat Change (%)		Common Snook Temperature Stress and Habitat Change (%)
	Chronic: Water > 20° C over coldest 72 h	Acute: Water > 15° C over coldest 4 hours	Most sensitive 24 hours >15° C
Volume	10%	8%	6%
Area	10%	6%	5%

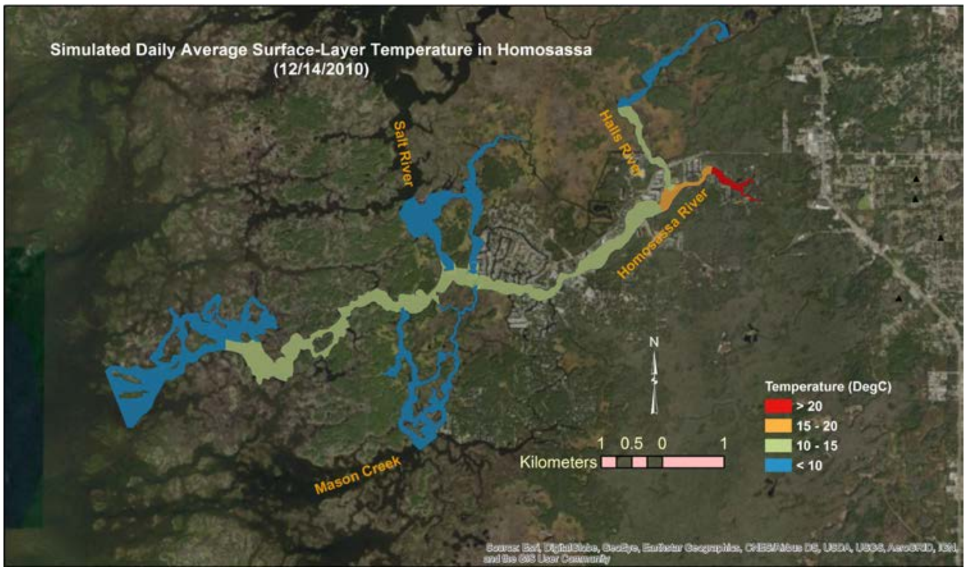


Figure 6-2. Common Snook temperature-based habitat in the Homosassa River System; 12/14/2010.

CHAPTER 7 - MINIMUM FLOWS RECOMMENDATION FOR HOMOSASSA RIVER SYSTEM

7.1 Basis of Minimum Flows Recommendation

Minimum flows are designed to predict environmental effects of withdrawal impacts and determine the point at which further withdrawal-related reductions in flow would cause significant harm. We identified, developed and used four primary elements for identifying numeric recommendations for a minimum flow reevaluation for the Homosassa River System. The four elements included: 1) a groundwater-flow model which predicts effects of existing and projected future withdrawals on flows described in Chapter 5; 2) a hydrodynamic model which predicts effects of reduced flows on surface water levels, salinity and temperature (Chapter 6); 3) environmental values considerations of potential impacts of flow reductions on water quality (Chapter 3); and 4) environmental values considerations of biological components of the system (Chapter 4).

Present-day groundwater withdrawal impacts are estimated at a 1.9% reduction from unimpacted flows based on Northern District Model predictions. The most sensitive response among salinity- and temperature-based habitats predicts that flow reductions of 5% will reduce Common Snook temperature habitat on an areal basis by 15%, based on LAMFE model predictions (Table 6-5).

Review of the data resulting from extensive monitoring and analysis of water quality and biological aspects of the system indicate that flow reductions up to 5% will not have disproportionate, adverse effects on the system. Minimal effects on chlorophyll concentrations were identified, based on our assessment of risks associated with exceeding a defined 7.7 ug/L concentration. However, the identified risk of chlorophyll concentration change is not analogous to a 15% loss of habitat or resource and cannot be used to determine significant harm. Nonetheless, after determining significant harm at a 5% reduction in flows based on 15% loss of temperature-based habitats, we can predict the effects this flow reduction will have on chlorophyll concentrations in the system. The results of water quality analysis show that flow reductions of 5% will increase the risk of exceeding the 7.7 µg/L chlorophyll threshold by 8% according to BLUPs and by 12.5% according to BLUEs (Figure 3-36).

Biological components of the system, including fish communities (Johnson et al. 2017), vegetation (Water and Air Research, Inc. 2018a), and oysters (Water and Air Research, Inc. 2018b) have been extensively surveyed by the District and will continue to be monitored in the future. Attempts to directly quantify effects of flow reductions on fish and invertebrates have not been successful (Leeper et al. 2012, Heyl et al. 2012).

The criteria for establishing minimum flows must meet the highest standards for confidence in the accuracy and precision of predicted responses to flow reductions. The hydrodynamic modeling results presented here and detailed in Chapter 6, as well as in Chen (2011, 2019a) were used to develop the criteria for reevaluation of minimum flows for the Homosassa River System. These criteria included salinity and temperature based habitats. Confidence in the ability of the hydrodynamic modeling application to predict changes in salinity and temperature can be assessed through the verification statistics shown in Table 6-3. This hydrodynamic modeling application to this system represents the best information available for determination of minimum flows for the Homosassa River System.

In addition to the criteria used for establishing flows, much of the data and analysis presented in this report is treated as environmental values considerations that support the reevaluation of minimum flows for the system. For example, shoreline vegetation mapping, fish community surveys, and oyster health assessments are all directly related to environmental values for the system. It would be inappropriate to assume that because the biological, chemical, and physical components of this system described in the preceding chapters do not have direct quantifications of significant harm resulting from reduced flows, that they were not fully considered. However, the best available information does not currently include methods for direct estimation of impacts to these biological factors as a consequence of changing flows. What is known is that salinity and temperature have far-reaching effects on biological, chemical and physical components of this system. Thus, all environmental values are considered and protected under the salinity- and temperature-based criteria that were used for reevaluation of minimum flows for the Homosassa River System.

7.2 Environmental Values

Rule 62-40.473, F.A.C. within the Water Resource Implementation Rule dictates consideration of a suite of 10 environmental values when establishing minimum flows. The District's Minimum Flows and Levels Program addresses this requirement and all other relevant requirements expressed in the Water Resource Implementation Rule as well as those included in the Water Resources Act of 1972 that pertain to the establishment of minimum flows and minimum water levels. Environmental values assessments of the Rainbow River (HSW 2009) and for Blue Spring and Blue Spring Run (Wetland Solutions, Inc. 2006) provide case studies in addressing environmental values through minimum flows evaluations and serve as a basis for the following summary of the consideration of environmental values in our reevaluation of minimum flows for the Homosassa River System.

7.2.1 Recreation in and on the Water

Recreation in and on the water was considered through assessment of potential changes in water levels, salinity and temperature. Recreational swimming, boating, and tubing requires adequate water depth (HSW 2009). Fishing and wildlife observation are also common recreational activities (Wetland Solutions, Inc. 2006). Other environmental values, including fish and wildlife habitats and the passage of fish, estuarine resources, aesthetic and scenic attributes, water quality and navigation contribute to recreational use. Water levels in the Homosassa River System are tidally influenced, and reductions of up to 5%, based on the most sensitive response among the criteria used in our minimum flow reevaluation are not expected to decrease water levels. Recreation associated with water depths is therefore not expected to be impacted with implementation of the reevaluated minimum flows for the river system. Recreation associated with water salinities and temperatures includes fishing, wildlife observation, and swimming. These recreational activities will be protected by the salinity and temperature habitats modeled with the LAMFE described in Chapter 6.

7.2.2 Fish and Wildlife Habitat and the Passage of Fish

Fish passage is driven by water depth, which, in the Homosassa River System, is primarily a function of tides. Water depth is strongly affected by tidal, seasonal, and long-term sea level trends and variation, and is not therefore expected to substantially vary based on changes in spring flow. The fish community is characterized by a combination of freshwater and saltwater assemblages (Johnson et al. 2017). The spatial and temporal patterns of salinity and freshwater in the system are critical to maintaining this diverse fish community. Shoreline vegetation also provides fish habitat. Shoreline vegetation is healthy throughout the system (Water and Air Research, Inc. 2018a). Hydrodynamic (LAMFE) modeling of impacts on salinity-based habitats will protect fish habitat through maintenance of the natural salinity regime and the natural vegetated shoreline. Temperature-based habitats targeted Common Snook and Florida Manatee habitat requirements. Common Snook (*Centropomus undecimalis*) is one of Florida's most popular gamefish and were the third most commonly targeted gamefish on the Florida Gulf Coast in 2014 (Muller et al. 2015). Temperature-based habitat for Common Snook was the most sensitive criterion assessed, and a minimum flow as a 5% reduction from unimpacted flows is recommended to prevent a greater-than 15% loss of this habitat. The Florida Manatee (*Trichechus manatus latirostris*) is a native species classified as threatened under the federal Endangered Species Act. Manatee habitat use is determined by warm water availability during winter. Temperatures and adequate water depths for manatee during these coldest times were directly assessed using the hydrodynamic model (LAMFE) and not expected to be adversely affected through implementation of the reevaluated minimum flow.

7.2.3 Estuarine Resources

Estuarine resources are maintained through preservation of salinity fluctuations in an estuary (HSW 2009). The Homosassa River System is tidal throughout, and thus all of the resources assessed for reevaluation of minimum flows established for the system are "estuarine resources". Bathymetry, river bottom substrates, shoreline vegetation mapping, oyster and barnacle surveys, benthic invertebrate surveys, fish community surveys, water quality analyses, and all other status and trends in physical, chemical, and biological characteristics of the system are aimed at ensuring estuarine resources are protected.

7.2.4 Transfer of Detrital Material

Transfer of detrital material is typically realized through floodplain inundation, when large quantities of material are suspended and moved downriver in surface water driven systems. Detrital material also includes all plant and animal materials, such as senescent stems and leaves and animal waste. These materials are transported by net downstream movement of water. Sediment analysis found greater quantities of silt and organic material further downstream, indicating that detrital material is moved downstream in the Homosassa River System (Arcadis 2016). Minimum flows established based on salinity and temperature habitats are expected to preserve flows necessary for downstream transport of detrital material in this tidally driven system.

7.2.5 Maintenance of Freshwater Storage and Supply

Effects of current and projected water use are included in the Northern District Model predictions of withdrawal impacts on groundwater levels and spring flows that were used to support the minimum flow reevaluation. These predictions did not indicate that current or projected withdrawals would be limited by the reevaluated minimum flow. In addition, this environmental value is expected to be protected through inclusion of conditions in water use permits which stipulate that permitted withdrawals will not lead to violation of any adopted minimum flows and levels.

7.2.6 Aesthetic and Scenic Attributes

Aesthetic and scenic attributes of the river are inextricably tied to other values such as water quality, shoreline vegetation, fish communities, and Florida Manatee and Common Snook thermal refuge. All of these aspects have been directly monitored for status and trends. Effects of flow reductions on temperature and salinity were directly estimated as hydrodynamic (LAMFE) model output.

Filamentous algae are a nuisance and impacts of flows on filamentous algae growth has been considered in this reevaluation. Factors affecting filamentous algae growth in the Homosassa River system include salinity, light penetration, and nutrient concentrations (Hoyer et al. 2004). There is not enough data on filamentous algae in the Homosassa River System to test for a direct statistical relationship between flows and filamentous algae growth and abundance. However, relationships between flows and salinity, light penetration, and nutrients have been analyzed. Unfortunately, filamentous algae have salinity habitat requirements similar to beneficial SAV, and therefore managing for salinity-based habitats cannot be used to promote beneficial SAV growth while limiting filamentous algae growth (Hoyer et al. 2004). Light penetration is a product of clarity and depth. Clarity is driven primarily by chlorophyll and total suspended solids (TSS). Flow does affect chlorophyll, and potential effects are quantified in section 7.1 above. There are no significant trends between flow and TSS (section 3.5.3). Lastly, although there is a strong link between algal growth and nitrate concentration, results of water quality data show that nutrient concentrations, particularly nitrates and total nitrogen, will not increase as a consequence of decreasing flows (see Chapter 3). While water velocity may limit filamentous algae growth in other systems, in the Homosassa River system, water velocity is driven primarily by tides, not springflow, and therefore withdrawal impacts are not expected to affect filamentous algae growth by affecting water velocities.

7.2.7 Filtration and Absorption of Nutrients and Other Pollutants

Filtration and absorption of nutrients and other pollutants were considered by studying bathymetry, river bottom substrates and shoreline characterizations, water quality characterization (including impaired water body listings), water residence time, nitrate concentration, primary productivity, aquatic and semi-aquatic vegetation, thermally-based habitat for the water column, and salinity-based water column, river bottom and shoreline habitats. Additionally, the factors used to evaluate fish and wildlife habitats and the passage of fish, estuarine resources, and water quality environmental values were considered applicable to the filtration and absorption of nutrients and other pollutants.

A water quality analysis focused on status and trends in critical water quality parameters. The majority of flow in the system comes from spring vents. Therefore, most nutrients and other pollutants enter the system as spring flow. Flow reductions of up to 5% are not predicted to alter concentrations of nutrients and other pollutants.

7.2.8 Sediment Loads

As with the transfer of detrital material, sediment loads are not expected to be reduced in this system. Sediment loads typically increase during flood events, when floodplains are inundated, and large flows transport large quantities of sediment during these infrequent events. Spring systems are more consistent than surface water systems, and do not exhibit floods or bursts of sediment loading in the same way. Thus, changes in sediment loads with implementation of the reevaluated minimum flow are expected to be negligible.

7.2.9 Water Quality

Water quality was considered by assessing status and trends in water quality parameters, including impaired water body listings, water residence time, nitrate concentration, temperature, salinity, river bottom, and shoreline habitats.

When interpreting water quality data, it is critical to consider context. Factors such as where and when the data were collected, what analytes were measured, and what other data were collected in the same manner as part of a larger effort all matter for proper interpretation. For minimum flows evaluation, the most important aspect of water quality data is its relationship or trend with variation in flows: do water quality data indicate “improvement” with increased flows, where improvement is a decreased likelihood of impairment or other harm? Nitrate concentrations have increased in spring vent waters over time, according to data collected by the District as part of Spring Vents Project P889 (Figure 3-22). This increase in concentrations is noteworthy, with levels well beyond the TMDL concentration of 0.23 mg/L established for several Homosassa River System springs (Table 3-1), a consistent trend dating back to the early nineties and continuing into the most recent data collection events.

Implementation of minimum flows does not, however appear to be an effective tool for addressing increasing nitrate concentrations in spring vents within the District. There are eleven spring vents monitored in the Spring Vents Project P889 in the Homosassa River System. Nitrate is measured at all of them. Data collected at the SE Fork mainspring vent showed a significant linear relationship between flow and nitrate + nitrite concentration (Table 3-7). At the ten remaining springs, there were no relationships between nitrate and flows. The synthesis of this information is that decreased flows associated with withdrawal impacts will not cause harm by increasing nitrate concentrations in spring vent discharges.

In the river mainstem, nitrate concentrations steadily decline with location downstream according to both Coastal Rivers Project P108 data and the University of Florida 5 Rivers Project data

(Figure 3-10). While nitrates are managed in spring vents, surface water quality criteria focus on total nitrogen (Table 3-1). Although total nitrogen concentrations are often above the NNC for WBID 1345F (the Homosassa River Estuary), these concentrations have not increased over time on average (Figure 3-19), and at downstream locations are decreasing (Figure 3-20). There were no significant linear relationships found in the Coastal Rivers Project P889 or University of Florida 5 Rivers Project data between flow and total nitrogen (Janicki Environmental Inc. and WSP, Inc. 2018). Therefore, this is further evidence that withdrawal impacts will not cause harm by affecting total nitrogen concentrations.

Although withdrawals and decreased flows will not affect total nitrogen based on the information summarized above, there was some evidence from the University of Florida 5 Rivers Project data that chlorophyll concentrations will be increased by decreasing flows. This potential relationship served as the basis for a "post-hoc" analysis in which we asked: how will setting minimum flows based on hydrodynamic modeling of salinity-based and temperature-based habitats affect chlorophyll concentrations expressed as the risk of exceeding a threshold value of 7.7 µg/L in individual samples? We found that at a minimum flow equivalent to a 5% reduction from unimpacted flows, the relative risk of exceeding this 7.7 µg/L threshold increases by 8 to 12.5 percent, depending on the statistical method (Figure 2-37). The identified risk of chlorophyll concentration change is not analogous to a 15% loss of habitat or resource and cannot be used to determine significant harm. However, the relative risks of exceedance do show that flow has some effect on chlorophyll concentrations, and that those effects are not substantial enough to establish significant harm at flow reductions less than the 5% flow reduction recommended as the minimum flow through analysis of salinity-based and temperature-based habitats.

In summary, relevant water quality constituents have been thoroughly monitored and assessed for this minimum flows reevaluation. The recommended minimum flow expressed as an 5% reduction from unimpacted flows is protective of the water quality of the Homosassa River System.

7.2.10 Navigation

Navigation was considered by mapping water depth and physical characteristics of the system. Water depth necessary for navigation in the Homosassa River System is strongly affected by tidal, seasonal, and long-term sea level trends and variation, and is not therefore expected to substantially vary based on changes in spring flow. Thus, navigation is not expected to be affected by the allowable reduction in flow associated with the reevaluated minimum flow.

7.3 Minimum Flows

Minimum flows are defined as the limit at which further withdrawals would be significantly harmful to the water resources or ecology of the area. For the current reevaluation of minimum flows for the Homosassa River System, existing groundwater withdrawal impacts on flow were assessed with the Northern District Model, version 5 (NDM5), and determined to be a 1.9 percent reduction from the unimpacted flows (see Chapter 5). Additional flow reduction scenarios were modeled with a hydrodynamic (LAMFE) model, which was used to predict impacts to salinity and temperature-based habitats from reduced flows. Protection of salinity-based habitats constitutes protection for a wide variety of species including submerged aquatic vegetation, shoreline vegetation, blue crabs, oysters, other invertebrates, and fish. Temperature-based habitats were modeled specifically for manatee and Common Snook. Physical and chemical processes that are affected or driven by salinity are similarly protected through protection of salinity habitats. Temperature habitats were modeled specifically for manatee and Common Snook. Risk of exceeding a chlorophyll threshold was modeled as a function of flow reductions. These effects of flow on chlorophyll were considered as an environmental value assessment supporting the minimum flow determination.

The most sensitive salinity habitats were the bottom area and volume of water less than or equal to 2 practical salinity units (Table 6-4). The most sensitive temperature habitat was Common Snook habitat by area of water (Table 6-5). This temperature-based habitat exhibited the highest sensitivity to flow reductions, with a 15% reduction in habitat corresponding to a 5% reduction in flows from the unimpacted flows scenario. This flow reduction is within the recommended maximum presumptive 10% reduction due to groundwater pumping suggested by Gleeson and Richter (2017), who suggest that “high levels of ecological protection will be provided if groundwater pumping decreases monthly natural baseflow by less than 10% through time.”

Results from this current reevaluation of the Homosassa River System therefore indicate an appropriate minimum flow could be established at 95% of unimpacted flows. This is equivalent to allowing up to a 5% reduction from unimpacted flows. Withdrawal impacts were based on NDM results (Table 5-4). From Jan. 1, 1975 to Jan. 1, 2005, the impact was linearly increased daily from 0 to 1.1% because the 2005 withdrawal impact estimated with the NDM was 1.1%. For all dates from Jan. 1, 2005 to Jan1, 2010, the impact was linearly increased daily from 1.1% to 1.8% based on the 1.8% withdrawal impact for 2010 estimated with the NDM. For all dates from Jan. 1, 2010 to Jan. 1, 2015, the impact was linearly increased daily from 1.8% to 1.9% because the 2015 impact estimated with the NDM was 1.9%. For all dates from Jan. 1, 2019 onward, the impact was considered to be 1.9%. Daily unimpacted flows were calculated as impacted flows / (1- impact).

Minimum flows were calculated as unimpacted flows * 0.95 (Figure 7-1). Based on these data and calculations, the median gaged (impacted) flow was 146 cfs, the median unimpacted flow was 148 cfs, and the median minimum flow was 141 cfs (Table 7-2).

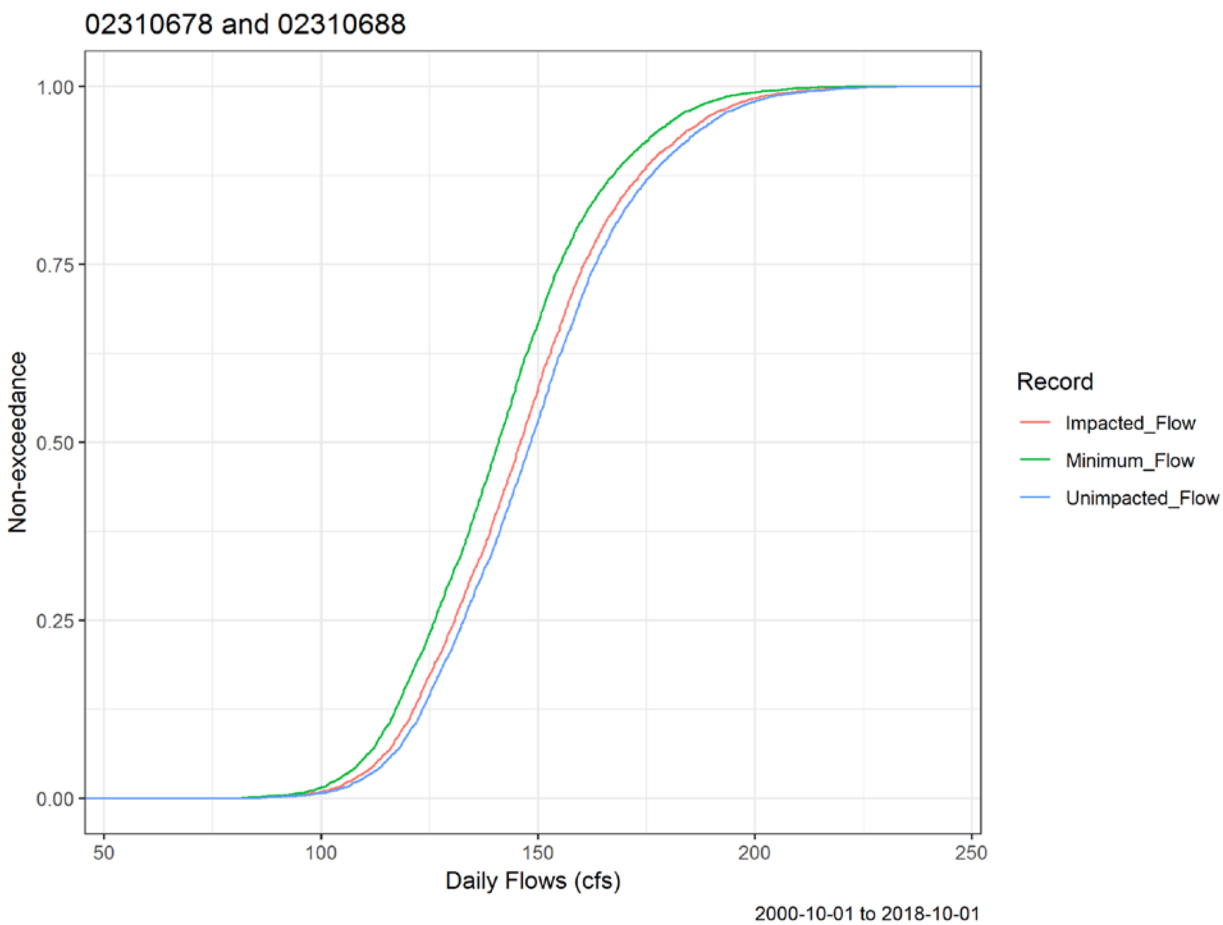


Figure 7-1. Daily flow scenarios for combined flow at the USGS Homosassa Springs at Homosassa Springs, FL (No. 02310678) and SE Fork Homosassa Spring at Homosassa Springs, FL (No. 02310688) gages.

Table 7-1. Flow statistics for combined gaged flows (Impacted), Unimpacted flows, and Minimum flows at the USGS Homosassa Springs at Homosassa Springs, FL (No. 02310678) and SE Fork Homosassa Spring at Homosassa Springs, FL (No. 02310688) gages. Data consists of 5,850 observations over 6,575 days from October 1, 2000 to October 1, 2018. Values in cubic feet per second (cfs).

Record	min	10th	25th	mean	median	75th	90th	max
Unimpacted	58	121	133	149	148	163	180	243
Impacted	57	119	131	147	146	161	177	240
Minimum	55	115	126	142	141	155	171	231

7.4 Minimum Flow Status Assessment and Future Reevaluation

District staff evaluated the current status of the flow regime of the Homosassa River System, numerical modeling results, and other supporting information to assess whether flows in the river are currently and are projected over the next 20 years to remain above limits associated with the currently proposed minimum flows. These assessments were completed because the Florida Water Resources Act of 1972 stipulates that If, at the time a minimum flow or minimum water level is initially established for a water body or is revised, the existing flow or level in a water body is below, or projected to fall within 20 years below, an applicable minimum flow or level, the DEP or the governing board as part of the regional water supply plan shall adopt or modify and implement a recovery strategy to either achieve recovery to the established minimum flow or level as soon as practical or prevent the existing flow or level from falling below the established minimum flow or level.

Based on the 1.9 percent impact from recent groundwater withdrawals on flows in the Homosassa River System modeled with the NDM5; District staff conclude the minimum flow proposed as a result of the current minimum flow reevaluation is being met. Similarly, based on a predicted impact of 2.5 percent associated with projected 2040 withdrawals, and a predicted 2.1 percent flow impact associated with projected 2040 withdrawals and planned conservation and reuse projects, the proposed minimum flow for the Homosassa River System is also expected to be met during the coming 20 years. Development and adoption of a recovery strategy or specific prevention strategy in association with adoption of the proposed minimum flows is, therefore, not necessary at this time.

Because climate change, structural alterations and other changes in the watershed and groundwater basin contributing flows to the Homosassa River System may affect flows in the system, and because additional information relevant to minimum flows development may become available, the District is committed to periodic reevaluation and if necessary, revision of the recommended minimum flows for this priority water body that will presumably be incorporated into Chapter 40D-8, F.A.C.

In support of this commitment, the District, in cooperation with the USGS, will continue to monitor and assess the status of flows in the river system and continue to work with others on refinement of tools such as the NDM5 that were used for development and assessment of the proposed minimum flow. Minimum flow status assessments for the Homosassa River System will be completed by the District on an annual basis, on a five-year basis as part of the regional water supply planning process, and on an as-needed basis in association with permit and project activities.

The District protocol for addressing sea level change when establishing minimum flows and levels states that information on sea level rise (SLR) should be used as a tool to determine if system reevaluation may be warranted (SWFWMD 2015). Sea level rises are calculated from the middle of the simulation period (in this case 2012) until the end of the current District planning horizon in 2035.

The United States Army Corps of Engineers (USACE) provides SLR estimates at their web site, http://www.corpsclimate.us/ccaceslcurves.cfm, where three types of the SLR can be obtained at several NOAA stations along the Florida Gulf coast: a low estimate, an intermediate estimate, and a high estimate. The closest NOAA stations to the mouth of the Homosassa River are Stations #8726724 (Clearwater Beach FL) and #8727520 (Cedar Key FL). The Clearwater Beach station is about 89,316 m south - southwest of mouth of the Homosassa River and the Cedar Key station is about 51,774 m northwest of the Homosassa mouth. The St. Petersburg station is further south from the mouth of the Homosassa River with a distance of about 114,790 m but has a longer period of record of water level data than the Clearwater Beach station does. As such, the St. Petersburg station is considered as a better station for the SLR estimation than the Clearwater Beach station. Based on this consideration, the low, intermediate, and high sea level rise estimates at the mouth of the Homosassa River in from 2012 to 2035 were calculated from those at the St. Petersburg and Cedar Key stations using an inverse distance weighting interpolation (Table 7-1). Over the 23-year period, estimated low, intermediate, and high SLRs at the mouth of the Homosassa River are 4.741, 8.588, and 20.990 cm, respectively.

These sea level rise values were added onto boundary conditions at the mouth of the Homosassa River and scenario runs were repeated under minimum flows and unimpacted conditions. The minimum flows scenario was based on a 5% reduction from unimpacted flows based on results of Common Snook temperature-based habitat analysis, which showed a 15% reduction in Common Snook warm water habitat (Table 6-5). These sea level rise simulations showed that at low, intermediate, and high rates of sea level rise, salinity-based habitats will not be decreased by more than 9%. This indicates that potential changes in salinity-based habitats will not prompt a reevaluation based on sea level rise. Effects of a 5% reduction in flows on chronic manatee temperature-based habitats will decrease habitat by maximum of 10%. Acute manatee temperature habitats will be reduced by 19% on a volume basis and by 23% on an area basis, both under intermediate sea level rise (Chen 2019a). These reductions in habitat greater than the 15% standard for significant harm indicate that reevaluation may be necessary to ensure adequate manatee habitat. Likewise, Common Snook temperature-based habitat associated with a 5% reduction in flow will be reduced by 18% on an area basis with the USACE high rate of sea level rise and by 17% on a volume basis (Chen 2019a). These increases in habitat loss with sea level rise argue for reevaluation prior to the end of the planning period in 2035.

Table 7-1. Sea level rise projections (cm) from 2012 to 2035 for three U.S. Army Corps of Engineers seal level rise projections at two National Oceanic and Atmospheric Agency stations and estimated at the mouth of the Chassahowitzka River based on the NOAA data.

USACE Projection	St. Petersburg NOAA Station	Cedar Key NOAA Station	Homosassa Mouth (estimated)
Low	5.8	4.3	4.7
Med	10.1	7.9	8.6
High	22.3	20.4	21.0

CHAPTER 8 - LITERATURE CITED

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CHAPTER 9 - APPENDICES (BOUND SEPARATELY)